THEME 4: Noise

This is a deliverable from the BalticBOOST project that was coordinated by HELCOM and co-financed by the European Union in 2015-2016 as part of the programme DG ENV/MSFD Action Plans/2016.

WP 4.1 Deliverable 4: Principles for defining levels of underwater noise that are consistent with GES for noise-sensitive species as well as decision support trees for establishing environmental targets for ambient and impulsive noise

Partners: [1]Baltic Marine Environment Protection Commission (HELCOM), [2]Swedish Defence Research Agency (FOI)

Authors: Henriette Schack[1], Marta Ruiz[1], Peter Sigray[2] and Mathias Andersson[2]

Contents

1 Introduction

BalticBOOST had the task to develop principles for defining levels of underwater noise that are consistent with GES for noise-sensitive species. The principles are meant to facilitate a coherent approach among the countries, and outline what would be considered good environmental status in relation to noise.

The content of this document has been considered by HELCOM PRESSURE 5-2016 (Outcome of PRESSURE 4-2016, par. 4.12-4.20) and GEAR 15-2016 (Outcome of GEAR 15-2016, par. 4.10-4.19), and has been submitted to HELCOM 38-2017 with the recommendation to support the document and use it to guide further work on GES and provide input to the MSFD TG Noise and OSPAR. Continued work in HELCOM is proposed to be taken forward by the HELCOM EN-Noise.

2 Background to underwater noise

2.1 Anthropogenic sources of underwater noise

A wide range of off-shore construction work and other human activities occur in the Baltic Sea area (see e.g. Baltic SCOPE project), and all of these activities produce sound either deliberately (e.g. seismic surveys) or as a by-product. The most significant man-made sources of loud impulsive noise are explosions, pile driving, seismic explorations and low frequency sonars, whereas human-generated noise of a more continuous nature encompasses sources such as energy installations, continuous dredging, shipping, or renewable energy operations.

2.2 Noise and aquatic animals

Sound propagates well over long distances in the aquatic environment (Medwin and Clay, 1998), and many aquatic animals rely on sound for communication, orientation and finding prey. Marine mammals in the Baltic Sea (the grey, harbour and ringed seals, and the harbour porpoise) all have acute underwater hearing abilities (Kastelein et al., 2010, Reichmuth et al., 2013) and use sound for navigation through echolocation (harbour porpoises) or passive listening (seals). Some Baltic fish species such as herring and cod, both of which also hear well, though mostly at low frequencies (Enger, 1967, Sand and Enger, 1973), may rely on passive listening in some situations. Sound is also used for communication between conspecifics and during different specific activities e.g., mating, spawning, schooling and aggression (Clausen et al., 2010; van Parijs et al., 2003a, b; Wahlberg and Westerberg, 2003, Wilson et al., 2004, Hawkins and Rasmussen, 1978) and sound detection may be important in predator/prey interactions, whether a predator is trying to locate a prey, or a prey is trying to avoid detection and capture (Dehnhardt et al., 2001, Karlsen et al., 2004).

Sound which clutters and masks sounds of interest is generally defined as noise (Richardson et al., 1995), and increasing noise levels can be problematic to the species relying on sound for vital parts of their life cycle.

Noise may disrupt behaviours, increase stress levels, mask important signals and/or reduce the hearing sensitivity either temporarily or permanently in an individual (Richardson et al., 1995; Southall et al., 2007; Schreck, 1996; Sierra-Flores et al., 2015; Atkinson et al., 2015). Effects of noise on individuals have the potential to decrease fitness and could potentially lead to reduced recruitment to the next generation thereby affecting a population.

There is increasing knowledge base on noise impacts on individual fish and marine mammals (see Popper and Hawkins, 2012 2016), but to which extend this can be translated into fitness effects and ultimately population effects is not known at present, but may be available in future.

A list of priority noise-sensitive species in the Baltic Sea has been identified based on hearing sensitivity, threat status, commercial value, spatial distribution and data availability. It consists of the four Baltic marine mammal species: harbour porpoises, ringed seals, harbour seals, and grey seals, as well as three species of fish: cod, sprat and herring. For further information please see the Report on noise sensitivity of animals in the Baltic Sea (WP 4.1 Deliverable 3). The report has been approved for publication in the HELCOM Baltic Sea Environment Proceedings series (Outcome of HOD 51-2016, par. 6.88) to take place in 2017.

2.3 Areas of significance for noise sensitive species

Information on areas of significance for the prioritized noise sensitive species as well as information on the times of year, when these areas are of special importance (e.g. cod spawning areas in spawning season), has been used when developing the guidelines establishing environmental targets for underwater noise. Such background information was collated in the report on noise sensitive species recently approved by HELCOM.

Table 1 and Figure 1 summarize important spatio-temporal information for the prioritized noise-sensitive species in the Baltic Sea, where such information is available. For harbour porpoises the identified areas are based on established and proposed marine protected areas (HELCOM MPA database; Calrström and Carlén, 2016) identified as important areas based on tagging and acoustic survey data (Teilman, 2008; Sveegaard et al. 2011a; Sveegaard et al., 2011b, SAMBAH, 2015; Calrström and Carlén, 2016). Based on comments received at GEAR 15-2016 (Outcome of GEAR 15-2016, para. 4.12) additional sensitive areas for harbour porpoises in the Western Baltic Sea (Pomeranian Bay and protected areas east of Rügen as well as Puck Bay) were included in the map of sound sensitive areas. For harbour seals and grey seals the identified areas are based on data of identified haul-outs (HELCOM SEAL EG, 2015, for the HELCOM core indicator on "Distribution of Baltic seals" (unpublished, http://www.helcom.fi/baltic-sea-trends/indicators/distribution-of-baltic-seals/contributors-and-references/). For ringed seals the identified areas are based on data from marine protected areas, where this species is included as part of the designation basis (HELCOM MPA database).

For the fish species the Bornholm Deep, and Arkona basin can be identified as areas of high interest for cod and sprat during spawning in spring and summer (Warner et al. 2012), and for sprat the Northern deep, Gotland deep, and Gdansk deep can also be identified during the spawning period (Warner et al. 2012; Ojaveer and Kalejs, 2010). For herring the area around Rügen is identified as of particular importance for spawning (Warner et al. 2012).

This preliminary map is based on available knowledge. Areas may be added or changed, as more information becomes available.

Table 1 Periods of biological significance for each of the identified priority noise sensitive species. Periods not applicable to a species are marked in blue.

Species	Calving/Pupping period	Mating/spawning period	Nursing Period	Moulting period	References
Harbour porpoise (*Phocoena phocoena*)	June-July	August	June/July through the fall months	N.A	Lockyer, 2003; Bjørge, 2009
Harbour seal (*Phoca vitulina*)	June	July-August	4 weeks	August	Jørgensen, 2003; Burns, 2009
Ringed seal (*Phoca hispida botnica)*	February-March	Thought to occur immediately after weaning of the pup	4-6 weeks	Mid-April – early May	Sinisalo et al., 2008; Hammill, 2009; HELCOM red list species data sheet 2013
Grey seal (*Halichoerus grypus*)	February-March	March-April	2 weeks	June	Bonner, 1979; Hall, 2009; HELCOM red list species data sheet 2013
Cod (*Gadus morhua*)	N.A	March-December	N.A	N.A	BALANCE, 2007; Warnar et al., 2012
Herring (*Clupea harengus*)	N.A	Spring and autumn	N.A	N.A	Warnar et al., 2012
Sprat (*Sprattus sprattus*)	N.A	March-August	N.A	N.A	BALANCE, 2007

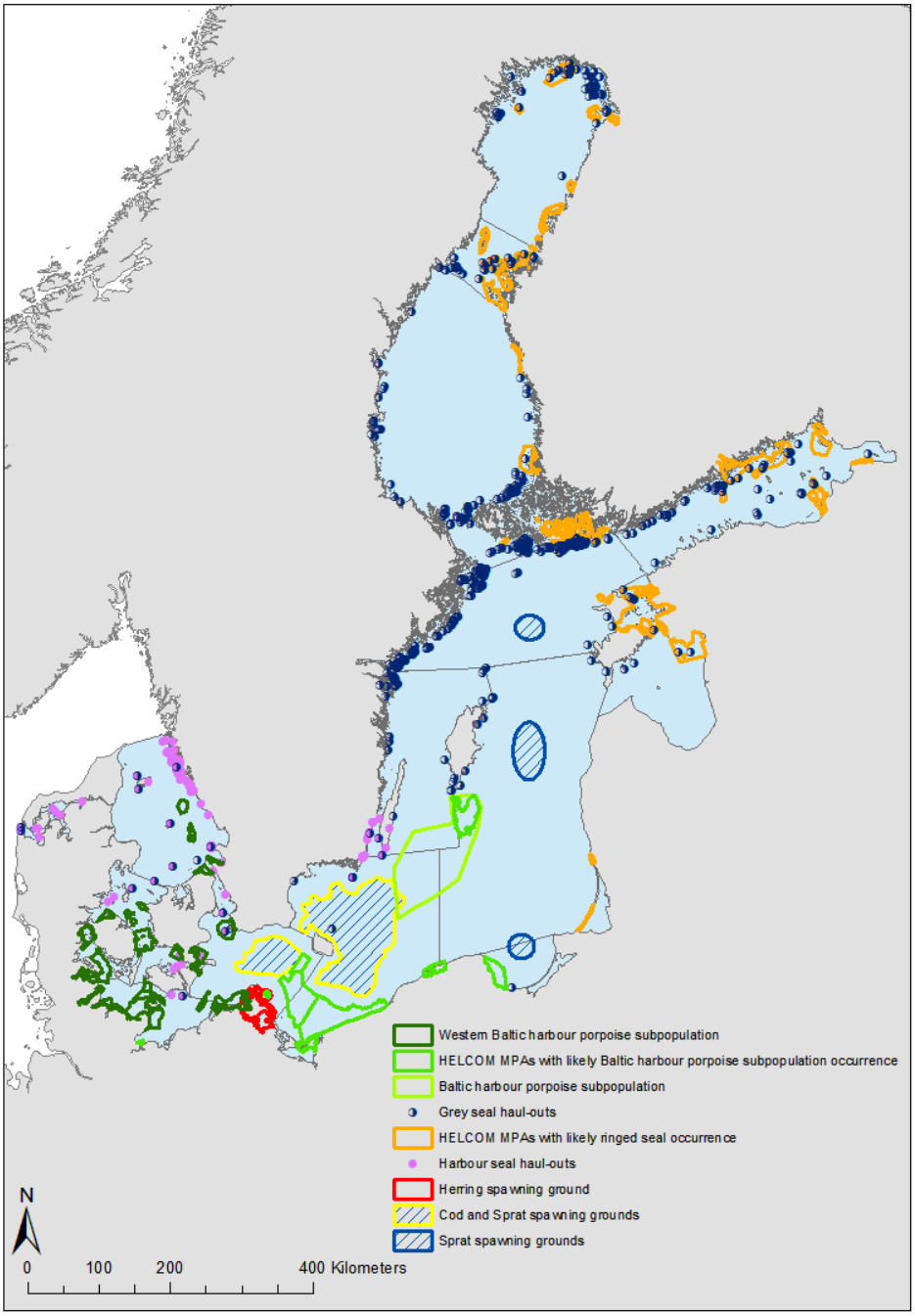

Figure 1. Preliminary biologically sensitive areas. For harbour porpoises important areas are based on established marine protected areas (MPA) where this species occur as well as recent findings. For the Western Baltic subpopulation, important areas are based on tagging and acoustic survey data (dark green squares, Teilmann et al., 2008; Sveegaard et al., 2011a and b). For the Baltic subpopulation important areas are based on acoustic survey data (light green squares, Carlström and Carlén, 2016) and MPA where this species occur (HELCOM MPA database; Calrström and Carlén, 2016). For harbour seals, areas are based on data of identified haul-outs (pink dots, HELCOM SEAL EG, 2015, for the HELCOM core indicator on "Distribution of Baltic seals", unpublished). Important areas for ringed seals are based on MPA where the species occurs (orange, HELCOM MPA database). For grey seals, areas are based on data of identified haul-outs (HELCOM SEAL EG, 2015, for the HELCOM core indicator on "Distribution of Baltic seals" haul-outs) (blue and white dots, HELCOM SEAL EG, 2015, for the HELCOM core indicator on "Distribution of Baltic seals", unpublished). For the fish species important areas are based on known spawning grounds. Sprat spawning grounds (blue squares, Warnar et al. 2012; Ojaveer and Kalejs, 2010), common cod and sprat spawning grounds (yellow squares, Warner et al. 2012), and one of the most important spawning grounds for herring in the south western Baltic Sea (red squares, Warner et al. 2012). More sites may be added as data becomes available.

2.4 Existing GES assessments for marine mammals

The environmental status for some of the priority noise-sensitive species in the Baltic is already being assessed under the HELCOM Core Indicators on 'Populations trends and abundance of seals' and 'Distribution of Baltic seals'. The assessments are done based on abundance and population growth rate (population trend), and on distribution relative to pristine distribution as seen e.g. 100 years ago, or occupation of currently available haul-out sites. Threshold values for the different populations is achieved when the species specific growth rate is achieved, when there is a certain abundance of individuals in each management unit, and when all available haul-outs are occupied with no decrease in area of occupation. The current environmental status for those animals where GES is assessed, is proposed to be used as a source of information when identifying areas in which environmental targets should be established (Figure 2 and Figure 3).

The current status of seals is summarized in Table 2. The assessment of seal status is from the latest HELCOM Core Indicator report on Populations trends and abundance of seals and revised HELCOM Core Indicator on Distribution of Baltic seals, submitted to the SEAL-EG in the SEAL 10-2016 meeting. For harbour porpoises there are no agreed indicator or assessment results within HELCOM.

Table 2. Current status assessment of harbour seal, ringed seal, grey seal, and harbour porpoise showing the assessment (red = sub-GES; green = GES) for each management unit. For seals it is in reference to abundance, growth rate, and distribution, and the assessment is from the latest HELCOM Core Indicator reports on Populations trends and abundance of seals and Distribution of Baltic seals, submitted to the SEAL 10_2016 meeting. For harbour porpoises a qualitative assessment was done within the CORESET I project, and is the one presented.

Species	Management unit	Population trend (growth rate) and Abundance	Distribution
Harbour seal	Limfjord		
	Kattegat		
	Southern Baltic		
	Kalmarsund		
Ringed seal	Bothnian Bay		
	Gulf of Finland, Archipelago Sea, Gulf of Riga, and Estonian coastal waters		
Grey seal	Baltic Sea		
	Southwestern Baltic		
Harbour porpoise	Baltic Proper		
	Southwestern Baltic		

3. Principles for defining levels of impulsive and continuous underwater noise consistent with GES for sound-sensitive species

Effects of noise on the level of population are not yet understood, and GES for populations has therefore not yet been defined for underwater noise.

Tables 3 and 4 outline a qualitative description of conditions to be met to consider GES to be achieved and are meant to facilitate a coherent approach among the countries. They are meant to be used to develop guidance levels or thresholds of noise consistent with good environmental status for the individual species and furthermore the development of environmental targets, i.e. the reduction in pressure needed to reach GES, if evaluated as needed (Figure 2).

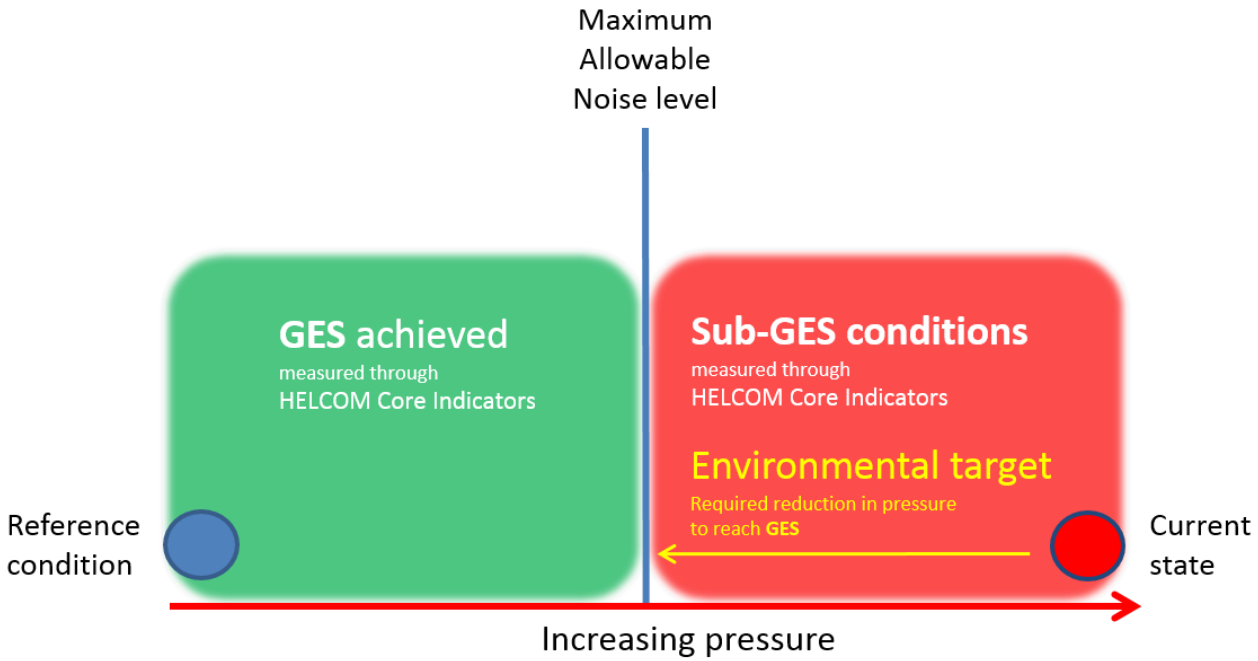

Figure 2. Schematic representation of the relationship between GES condition (green area), sub-GES conditions (red area), maximum allowable noise level consistent with GES (vertical blue line) and the environmental target (yellow arrow of reduced pressure required to reach GES) in reference to the horizontal increased pressure (red arrow).

As "regional input" they will be used to seek synergies with the work of OSPAR and EU TG Noise. Also the international framework provided by the IMO (in relation to continuous noise) could be built upon when utilizing the proposed regional input for further work.

Table 3. Regional input for defining levels of impulsive underwater noise consistent with GES for sound-sensitive species[1].

Species	Principles for defining levels of impulsive underwater noise consistent with GES
Harbour porpoise (*Western Baltic and Baltic Proper subpopulations*)	– Individuals should not be exposed to anthropogenic noise levels high enough to induce injury. – [2]Significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided. – Noise level should not affect the energy budget of individual animals nor breeding to a degree likely to affect the population significantly; particular emphasis should be on calving and nursing grounds.
Harbour seal (*Western Baltic and Kalmarsund sub-populations*)	– Individuals should not be exposed to anthropogenic noise levels high enough to induce permanent hearing loss. – [3]Significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided. – Noise level should not affect the energy budget of individual animals nor breeding to a degree likely to affect the population significantly; particular emphasis should be on haul-outs sites.
Ringed seal	– Individuals should not be exposed to noise levels high enough to induce permanent hearing loss. – [4]Significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided. – Noise level should not affect the energy budget of individual animals nor breeding to a degree likely to affect the population significantly; particular emphasis should be on haul-outs sites.
Grey seal	– Individuals should not be exposed to noise levels high enough to induce permanent hearing loss. – [5]Significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided. – Noise level should not affect the energy budget of individual animals nor breeding to a degree likely to affect the population significantly; particular emphasis should be on haul-outs sites.
Cod	– Noise levels high enough to induce significant behavioural disruption at a population level should be avoided in spawning areas at critical timing.
Sprat	– Noise levels high enough to induce significant behavioural disruption at a population level should be avoided in spawning areas at critical timing.
Herring	– Noise levels high enough to induce significant behavioural disruption at a population level should be avoided in spawning areas at critical timing.

[1] Denmark and Russia have a study reservation on the principles for defining levels of impulsive underwater noise consistent with GES for sound-sensitive species.
[2] Danish suggestion (e-mail 20.12.2016) in order to make the principles consistent in terms of wording: 'Noise level that induce significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided.'
[3] Danish suggestion (e-mail 20.12.2016) in order to make the principles consistent in terms of wording: 'Noise level that induce significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided.'
[4] Danish suggestion (e-mail 20.12.2016) in order to make the principles consistent in terms of wording: 'Noise level that induce significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided.'
[5] Danish suggestion (e-mail 20.12.2016) in order to make the principles consistent in terms of wording: 'Noise level that induce significant loss of habitat through displacement for a significant period of time that is likely to affect population should be avoided.

Table 4. Regional input for defining levels of continuous underwater noise consistent with GES for sound-sensitive species[6]

Species	Principles for defining levels of continuous underwater noise consistent with GES
Harbour porpoise	– Noise level should not affect the energy budget nor breeding to a degree likely to affect the population significantly; particular emphasis should be on calving and nursing grounds – Noise should not be at levels that induce masking leading to significant negative change in population growth rate
Harbour seal/Ringed seal/Grey seal	– Noise level should not affect the energy budget nor breeding to a degree likely to affect the population significantly; particular emphasis should be on breeding and areas around haul outs – Noise should not be at levels that induce masking leading to significant negative change in population growth rate; particular emphasis should be on mating sites and areas around haul outs.
Cod/herring/sprat	– Noise in spawning areas at critical timing should not be at levels that induce significant behavioural disruption and/or masking leading to significant negative change in population growth rate.

4. Decision support trees for establishing environmental targets for ambient and impulsive noise[7]

Despite the lack of knowledge on GES for underwater noise, the risk of significant degradation in environmental status, in particular in relation to certain activities known to cause significant pressures on the environment, e.g. pile driving, may call for a more immediate reduction in pressure in certain areas. Risk-based decision support trees were proposed by the BalticBOOST project and further developed by the HELCOM BalticBOOST WS 1-2016 (Figure 3 and Figure 4). They are meant as a tool for identifying areas/situations where a reduction in pressure is needed. For full implementation, guidance levels should first be established based on the proposed principles defined in Tables 3 and 4. Draft guidance levels were proposed to the BalticBOOST workshop that agreed that they should be further developed under the HELCOM EN-Noise.

The risk based approach of the decision support trees to establish environmental targets involves focusing on areas where there is a current presence of a noise sensitive species, whether a noise generating anthropogenic event occurs in the area, and whether the noise levels generated exceed the guidance levels. Finally it also takes into account the current assessment of environmental status of the population of a noise sensitive species.

There is a need to further work on these decision support trees in order to make them operational, through defining guidance levels, and further development of the indicators on impulsive and continuous noise. However, decision support trees provide the basis for a coherent continuation of the initiated work in the HELCOM area.

[6] Denmark and Russia have a study reservation on the principles for defining levels of continuous underwater noise consistent with GES for sound-sensitive species.

[7] Denmark alternative proposal for the title (e-mail 20.12 2016): 'Decision support trees that may be used by member states as a guidance on how to establish environmental targets for ambient and impulsive noise when appropriate.'

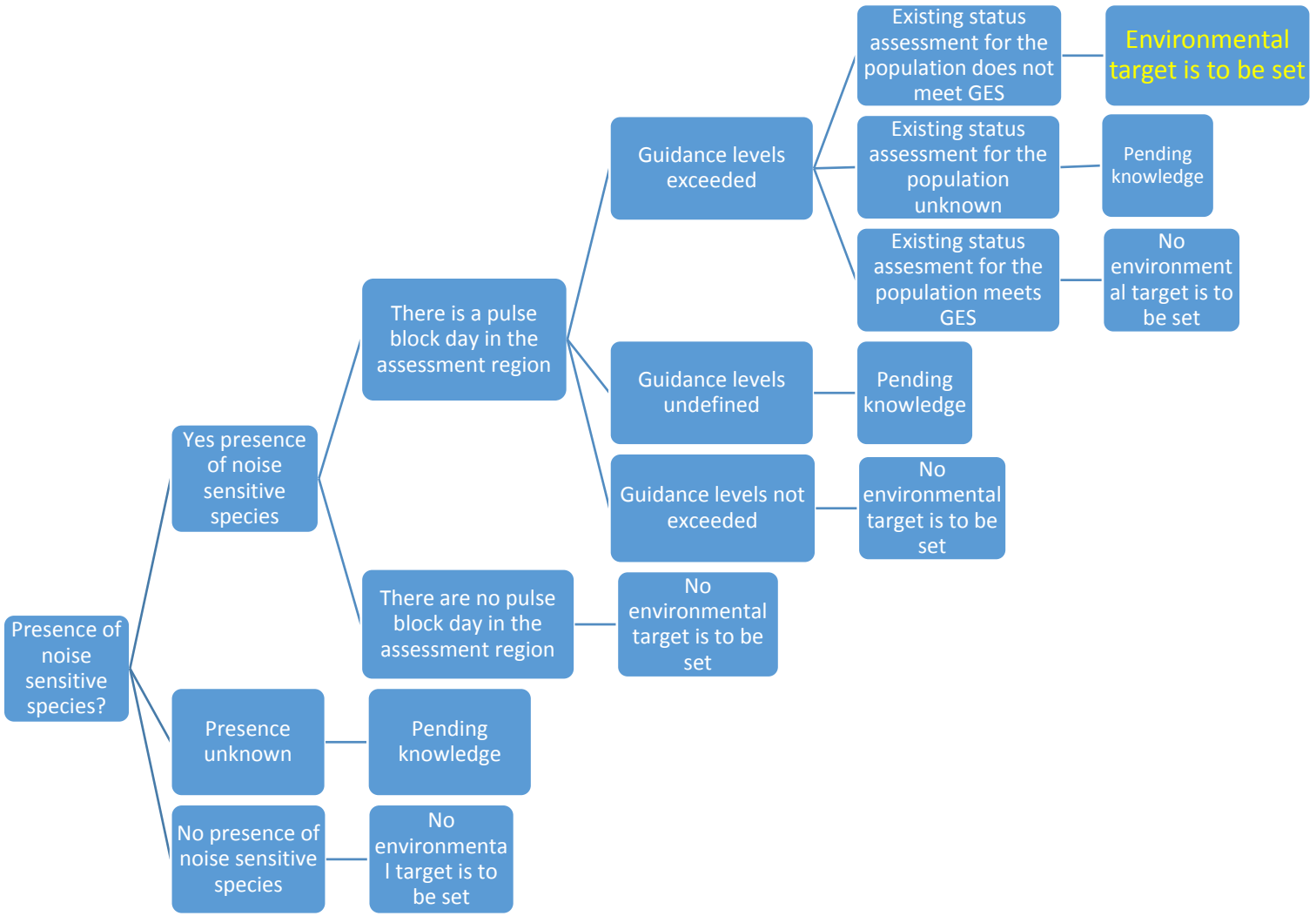

Figure 3. Decision support tree to be used for establishing environmental targets for impulsive noise events. In the situations where knowledge in pending, no environmental target can be established at present, but will be re-evaluated when new information (e.g. guidance levels becoming defined) becomes available. The existing status assessment is done based on abundance as well as population growth rate, and GES for the different species is achieved when the species specific growth rate is achieved and when there is a certain abundance of individuals in each management unit (HELCOM, 2015). It thus identifies populations where the pressure from noise could add to the total pressure on the population keeping it from reaching GES.

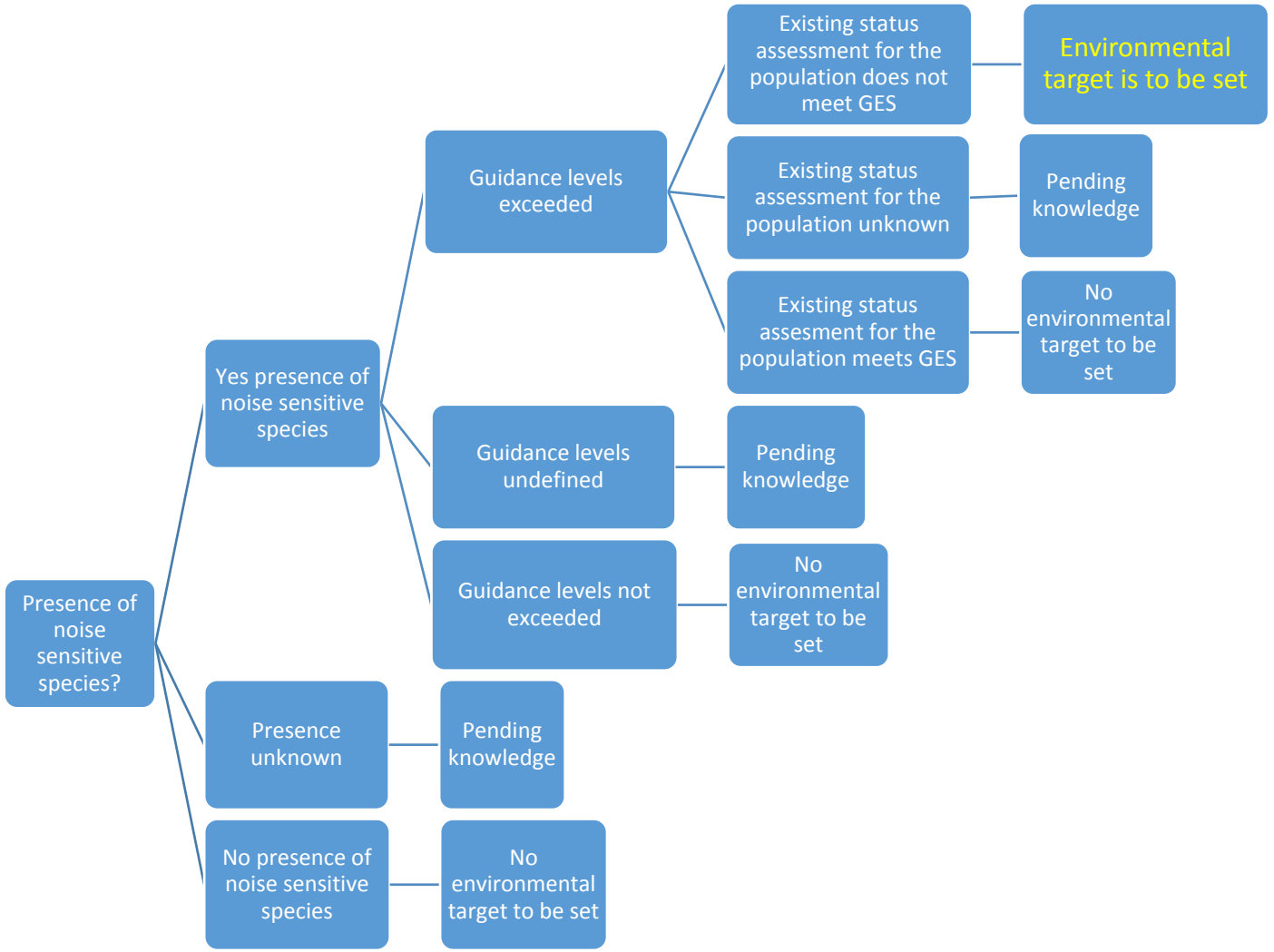

Figure 4. Decision support tree to be used for establishing environmental targets for continuous noise events. In the situations where knowledge in pending, no environmental target can be established at present, but will be re-evaluated when new information (e.g. guidance levels becoming defined) becomes available. The existing status assessment is done based on abundance as well as population growth rate, and GES for the different species is achieved when the species specific growth rate is achieved and when there is a certain abundance of individuals in each management unit (HELCOM, 2015). It, thus identifies populations where the pressure from noise could add to the total pressure on the population keeping it from reaching GES.

5. References

Atkinson, S., Crocker, D., Houser, D., Mashburn, K. 2015. Stress physiology in marine mammals: how well do they fit the terrestrial model? J. Comp. Physiol. B. 185: 463–486.

BALANCE. 2007. Pelagic habitat mapping: A tool for area-based fisheries management in the Baltic Sea. BALANCE Interim Report No. 20.

Bjørge, A. a. T., K. A. 2009. Harbor porpoise (*Phocoena phocoena*). In: Encyclopedia of Marine Mammals. W. F. Perrin, Würsig, B., Thewissen, J. G. M. (Eds.), Academic Press. pp 530-533.

Bonner, W. N. 1979. Grey seal. Mammals in the Seas, 2: 90-94.

Burns, J. J. 2009. Harbor seal and Spotted seal. In: Encyclopedia of Marine Mammals. W. F. Perrin, Würsig, B., Thewissen, J. G. M. (Eds.), Academic Press, pp. 533-542.

Carlström, J, Carlén, I. 2016. Skyddsvärda områden för tumlare i svenska vatten. AquaBiota Report 2016:04. 88 pp.

Clausen, K. T., Wahlberg, M., Beedholm, K. Deruiter, S., Madsen, P. T. 2010. Click communication in harbour porpoises Phocoena phocoena. Bioacoustics 20: 1-28.

Dehnhardt, G., Mauck, B., Hanke, W., Bleckmann, H. 2001. Hydrodynamic trail-following in harbor seals (Phoca vitulina). Science, 293: 102-104.

Enger, P.S. 1967. Hearing in herring. Comp. Biochem. Physiol., 22:527-538.

Hall, A., Thompson, D. 2009. Gray Seal (*Halichoerus grypus*). In: Encyclopedia of Marine Mammals. W. F. Perrin, Würsig, B., Thewissen, J. G. M.(Eds.), Academic Press, pp. 500-503.

Hammill, M. O. 2009. Ringed seal (*Pusa hispida*). In: Encyclopedia of Marine Mammals. W. F. Perrin, Würsig, B., Thewissen, J. G. M. (Eds.), Academic Press, pp 972-974.

Hawkins, A.D., Rasmussen, K.J. 1978. The calls of gadoid fish. J. Mar. Biol. Ass. U. K. 58: 891-911.

HELCOM. 2015. Population trends and abundance of seals. HELCOM core indicator report. Online.

Jørgensen, J. M. 2003. Introduktion til Chordatzoologi, Gads Forlag.

Karlsen, H. E., Piddington, R. W., Enger, P. S., and Sand, A. 2004. Infrasound initiates directional fast-start escape responses in juvenile roach Rutilus rutilus. Journal of Experimental Biology. 207: 4185-4193.

Kastelein, R.A., Hoek, L., de Jong, C.A.F., Wensveen, P.J. 2010. The effect of signal duration on the underwater detection thresholds of a harbor porpoise (Phocoena phocoena) for single frequency-modulated tonal signals between 0.25 and 160 khz. Journal of the Acoustical Society of America, 128: 3211-3222.

Lockyer, C. 2003. Harbour porpoises (*Phocoena phocoena*) in the North Atlantic: Biological

parameters. NAMMCO Sci. Publ. 5: 71-90.

Medwin, H., Clay, C.S. 1998. Fundamentals of Acoustical Oceanography. Academic Press, 711p.

Ojaveer, E., Kalejs, M. 2010. Ecology and long-term forecasting of sprat (*Sprattus sprattus balticus*) stock in the Baltic Sea: a review. Rev. Fish. Biol. Fisheries 20:203-217.

Popper, A.N., Hawkins, A. (eds). 2012. The effects of noise on aquatic life. Advances in experimental medicine and biology 730. Springer Science + Business Media LLC.

Popper, A.N., Hawkins, A. (eds). 2016. The effects of noise on aquatic life II. Advances in experimental medicine and biology 875. Springer Science + Business Media LLC.

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.

Richardson, W. J., Greene, C. R. Jr., Malme, C. I., Thomson, D. H. 1995. Marine mammals and noise. Academic Press, New York.

SAMBAH. 2015. Heard but not seen – Sea-scale passive acoustic survey reveals a remnant Baltic Sea harbour porpoise population that needs urgent protection. SAMBAH Non-technical report LIFE04 NAT/S/000261. http://www.sambah.org/Docs/General/Non-technical-report-v.-1.8.2.pdf.

Sand, O. & Enger, P. S. 1973. Evidence for an Auditory Function of Swimbladder in Cod. Journal of Experimental Biology, 59, 405-414.

Schreck, C. B. 1996. Immunomodulation: Endogenous Factors. In: The Fish Immune System: Organism, Pathogen, and Environment. G. Iwama and T. Nakanishi (Eds.). London: Academic Press. Vol. 15.

Sierra-Flores, R., Atack, T., Migaud, H., Davie, A. 2015. Stress response to anthropogenic noise in Atlantic cod Gadus morhus L. Aquacultural Engineering, 67: 67–76.

Sinisalo, T., Jones, R.I., Helle, E., Valtonen, E.T. 2008. Changes in diets of individual Baltic ringed seals (*Phoca hispida botnica*) during their breeding season inferred from stable isotope analysis of multiple tissues. Marine Mammal Science 24(1): 159-170.

Southall, B. L., Bowles, A. E., Ellison, W. T., Finneran, J. J., Gentry, R. L., Greene, C. R. J., Kastak, D., Ketten, D. R., Miller, J. H., Nachtigall, P. E., Richardson, W. J., Thomas, J. A. & Tyack, P. 2007. Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals, 33, 411-521.

Sveegaard, S., Teilmann, J., Tougaard, J., Dietz, R., Mouritsen, K. M., Desportes, G., Siebert, U. 2011a. High-density areas for harbor porpoises (*Phocoena phocoena*) identified by satellite tracking. Marine Mammal Science. 27(1): 230-246.

Svegaard, S., J. Teilmann, P. Berggren, K. M. Mouritsen, D. Gillespie, J. Tougaard. 2011b. Acoustic surveys confirm the high-density areas of harbour porpoises found by satellite tracking. ICES Journal of Marine Science 68(5): 929-936.

Teilmann, J., Sveegaard, S., Dietz, R., Petersen, I.K., Berggren, P. & Desportes, G. 2008: High density areas for harbour porpoises in Danish waters. National Environmental Research Institute, University of Aarhus. 84 pp. – NERI Technical Report No. 657.

Van Parijs, S.M., Corkeron, P.J., Harvey, J., Hayes, S.A., Mellinger, D.K., Rouget, P.A., Thompson, P.M., Whalberg, M., Kovack, K.M. 2003a. Patterns in the vocalizations of male harbour seals. J. Acoust. Soc. Am. 113(6): 3403-3410.

van Parijs, S. M. 2003b. Aquatic mating in pinnipeds: a review. Aquatic Mammals. Vol 29 (2): 214-226.

Wahlberg, M., Westerberg, H. 2003. Sounds produced by herring (Clupea harengus) bubble release. Aquatic Living Resources. 16: 271-275.

Warnar, T., Huwer, B., Vinther, M., Egekvist, J., Sparrevohn, C.R., Kirkegaard, E., Dolmer, P., Munk, P., Sørensen, T.K. 2012. Fiskebestandenes struktur - Fagligt baggrundsnotat til den danske implementering af EU's Havstrategidirektiv. DTU Aqua-rapport nr. 254-2012.

Wilson, B., Batty, R. S., Dill, L. M. 2004. Pacific and Atlantic herring produce burst pulse sounds. Proc. R. soc. Lond. 271: 95-97.