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Background

HOD 50-2016 approved organizing a two-day HELCOM workshop on underwater noise, supported by the BalticBOOST project (Outcome of HOD 50-2016, para. 4.66). The workshop, held 5-6 October 2016 in Copenhagen, Denmark, further developed principles for defining levels of underwater noise that are consistent with good environmental status (GES) for noise-sensitive species as well as decision support trees for establishing environmental targets for ambient and impulsive noise (Outcome of HELCOM BalticBOOST Noise WS 1-2016 WS).

Both the principles and the decision support trees have been developed with the aim of facilitating achieving good environmental status of a species in relation to its exposure to noise, and providing a basis for a regionally coherent approach for establishing environmental targets on underwater noise to be further developed in the frame of the HELCOM EN-Noise. Principles and trees are to be considered in line with the international framework provided by the IMO (in relation to continuous noise), OSPAR and the EU TG Noise.

The principles have been derived from gathered knowledge on (i) Baltic Species sensitive to noise (i.e. hearing sensitivity, threat status, commercial value, spatial distribution and data availability); and effects on these species of (ii) impulsive noise (i.e. animal displacement, injury and hearing damage to individuals); and (iii) continuous noise (i.e. masking of signals of importance for a species). The role of the decision trees is to articulate, through a risk based approach, the process of establishing environmental targets when needed. This need will depend on: (i) the presence of a noise sensitive species; (ii) the occurrence of a noise generating anthropogenic event; (iii) the exceedance of guidance levels; and (iv) the environmental status of the population measured by e.g. HELCOM core indicators on population abundance and health. The link between the principles and the trees is the guidance levels as the latter are to be defined in agreement with the principles. These guidance levels, preliminary defined as a range of acceptable noise rather than a precise level, are to be further developed by the HELCOM EN-Noise.

PRESSURE 5-2016 considered the recommended principles (Annex 5 of doc. 4-7) and agreed that the suggested principles are a fruitful way forward.

Denmark was of the opinion a final decision on HELCOM GES principles and threshold values should be in accordance to the draft proposal to revise the European Commission Decision on GES criteria, stating that threshold levels should be agreed upon at Union level, and Denmark therefore has a study reservation on the principles. Germany has a study reservation on principle one on impulsive noise for harbour porpoises and Pressure agreed that a new proposal for this specific principle would be circulated via the HELCOM EN-Noise and delivered to the upcoming GEAR meeting for consideration.

PRESSURE 5-2016 agreed to support national testing of the recommended decision-support trees for ambient and impulsive noise (Annex 3 and Annex 4 of doc. 4-7) and tasked the HELCOM EN-Noise to further develop them according to the conclusions from the workshop, taking into account a two weeks study reservation (by 11 November) by Russia. The meeting also took note that Denmark can support that the decision making trees are developed further with the understanding that it is a work in progress, and that there will be a possibility for Contracting Parties to evaluate the final approach.

This document contains the recommended 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.

Action required

The Meeting is invited to:

- provide feed-back to the recommended principles for defining levels of underwater noise that are consistent with GES for noise-sensitive species and agree what should be the next appropriate action; and
- support the national testing of the recommended decision support trees for establishing environmental targets for ambient and impulsive noise and task the HELCOM EN-Noise to further develop them according to the conclusions from the workshop and note the study reservation by Russia on the decision support trees to be clarified by 11 November 2016.

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

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.

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 mammals species: harbour porpoises, ringed seals, harbour seals, and grey seals, as well as three species of fish: cod, sprat and herring.

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 as when developing the guidelines establishing environmental targets for underwater noise. Such background information was collated in the report on noise sensitive species considered by STATE & CONSERVATION 4-2016 (doc. 6J-1), subsequently amended to include comments provided by the meeting as

well as those provided intersessionaly by Denmark and Poland The final version of the report was submitted to the noise workshop as background document.

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). 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

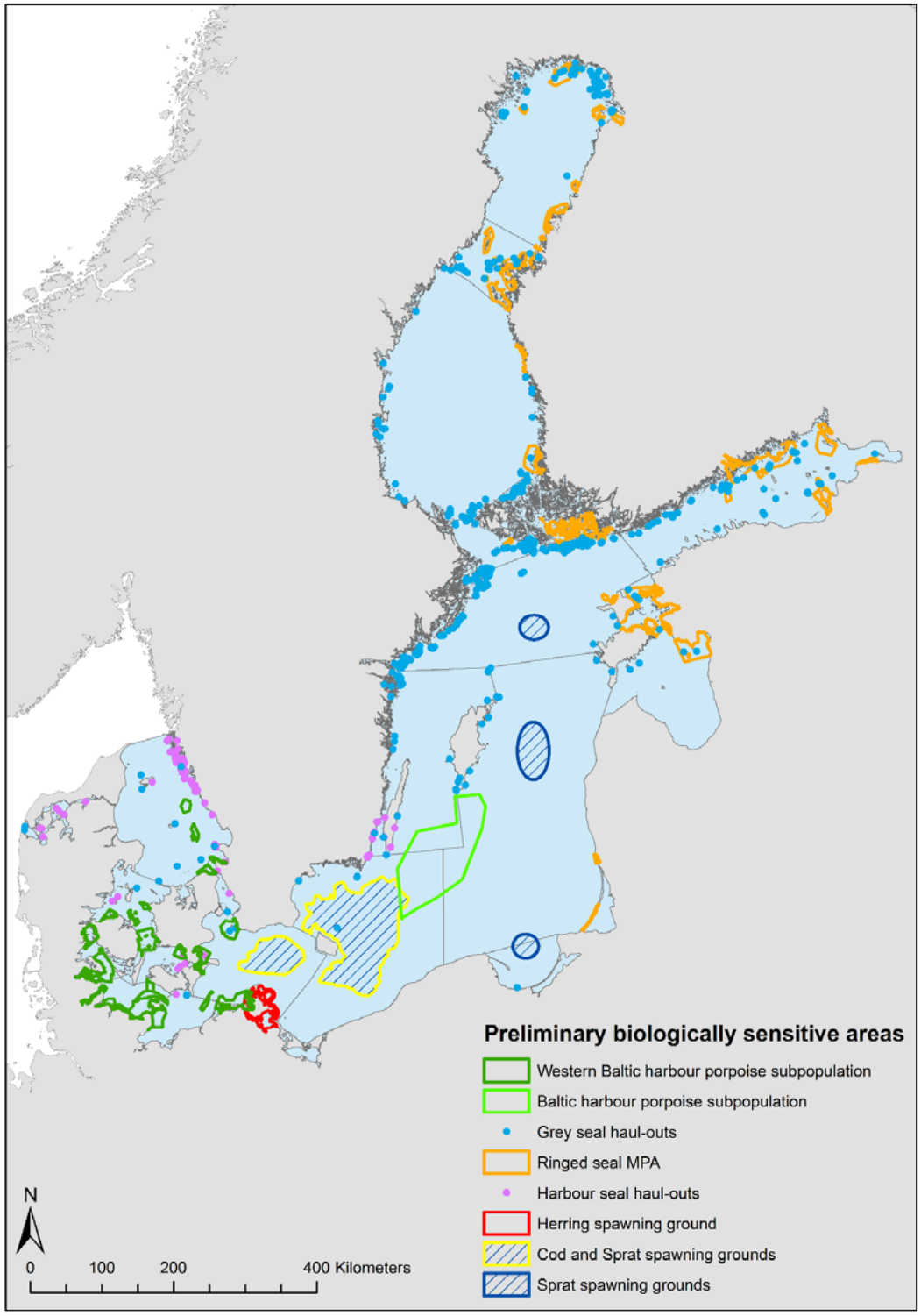

Figure 1 Preliminary biologically sensitive areas for harbour porpoises in the Western Baltic subpopulation (dark green, Teilmann et al., 2008; Sveegaard et al., 2011a and b), Baltic subpopulation (light green, Carlström and Carlén, 2015), haul-outs and possible mating grounds for harbour seals (red dots, 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/)), marine protected areas for Baltic ringed seals (orange, HELCOM MPA database), haul-outs and possible mating grounds for grey seals (yellow dots, 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/)), sprat spawning grounds (light blue, Warner et al. 2012; Ojaveer and Kalejs, 2010), cod spawning areas (dark purple, Warner et al. 2012), and one of the most important spawning grounds for herring in the south western Baltic Sea (light purple, Warner et al. 2012). More sites may be added as data becomes available.

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 are occupied. GES for the different species 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 to be considered 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. The assessment of harbour porpoises presented in Table 2 is taken from the qualitative assessment done by the CORESET I project.

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 CORSET 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		

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.

The principles presented below (Table 3 and Table 4) outline what would be considered good environmental status, and are to be used in discussing and subsequently develop levels of noise consistent with these principles. Further development of these principles is to take place in the frame of the HELCOM EN-Noise and in line with the international framework provided by the IMO (in relation to continuous noise), OSPAR and the EU TG Noise.

The principles are an expression of a common approach for the Contracting Parties to address the issue of noise in the Baltic Sea, and are part of the on-going work in HELCOM to move forward in dealing with underwater noise.

Table 3 Principles 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 permanent hearing loss.] [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. – 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. – 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. – 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 has a study reservation on the principles for defining levels of impulsive underwater noise consistent with GES for sound-sensitive species.

[2] This principle is to be amended based on the feedback provided by the HELCOM EN-Noise to a German rephrasing proposal. GEAR will be informed accordingly.

Table 4 Principles for defining levels of continuous underwater noise consistent with GES for sound-sensitive species[3]

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.

Decision support trees for establishing environmental targets for ambient and impulsive noise

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 2 and Figure 3). 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 defined based on the proposed principles defined in Table 2 and 3. 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. This is to be conducted within the frame of the HELCOM EN-Noise. However, decision support trees provide the basis for a coherent continuation of the initiated work in the HELCOM area.

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

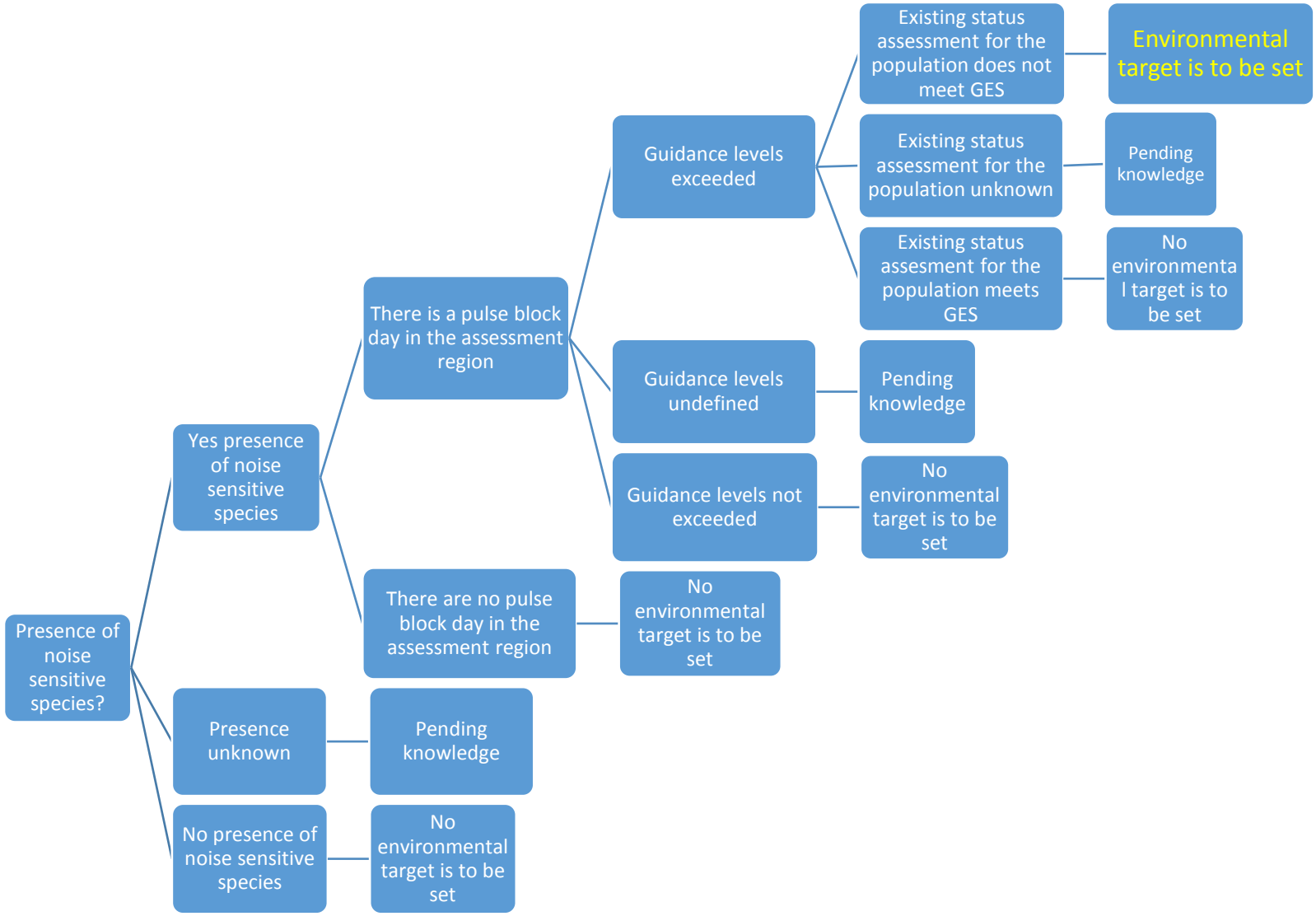

Figure 2 - Decision support tree to be used for establishing environmental targets for impulsive noise events. In the situations where knowledge in pending, no environmental target can be established at present, but will be re-evaluated when new information (e.g. guidance levels becoming defined) becomes 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.

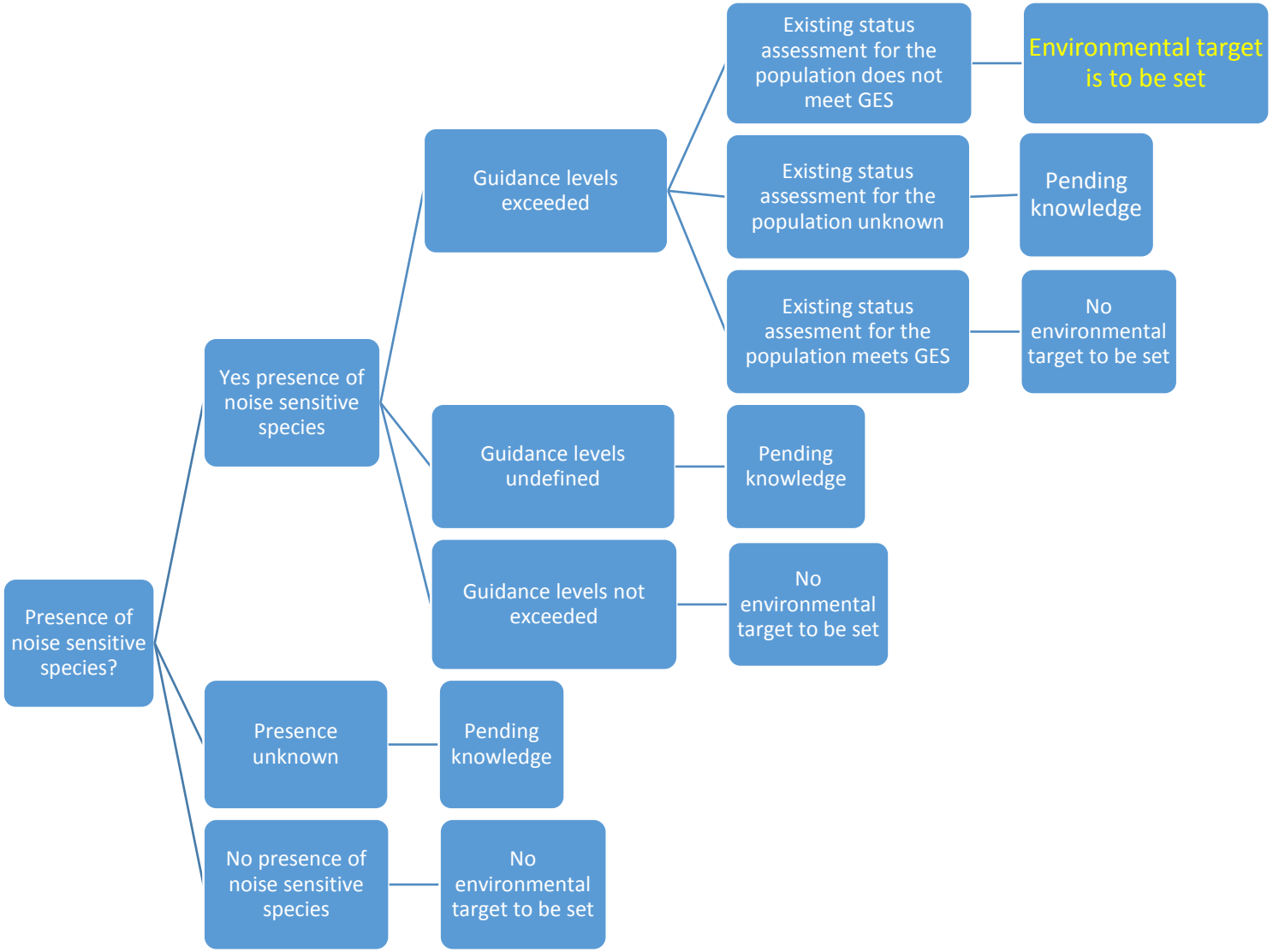

Figure 3- Decision support tree to be used for establishing environmental targets for continuous noise events. In the situations where knowledge in pending, no environmental target can be established at present, but will be re-evaluated when new information (e.g. guidance levels becoming defined) becomes 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.

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.