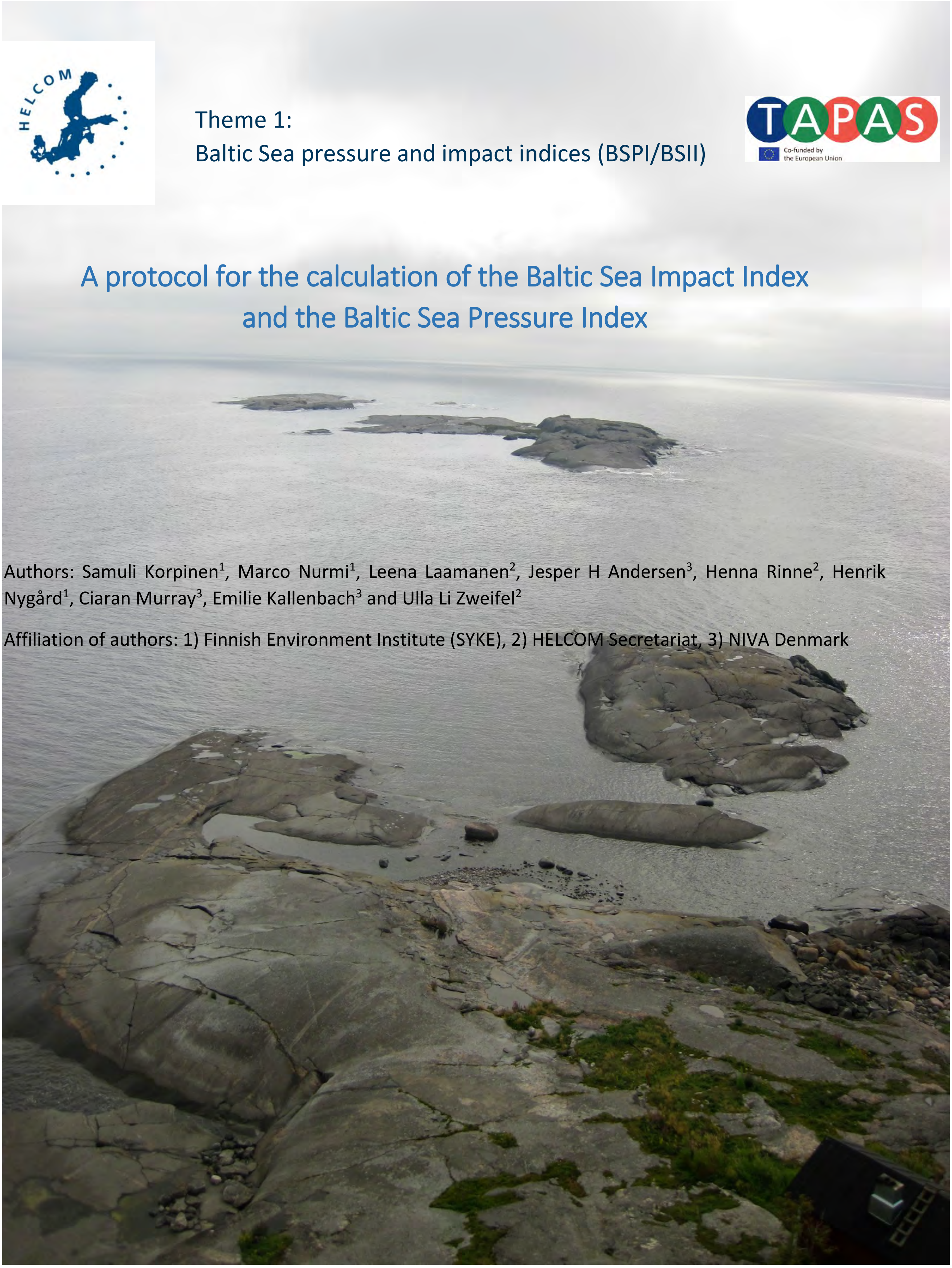

Theme 1:
Baltic Sea pressure and impact indices (BSPI/BSII)

A protocol for the calculation of the Baltic Sea Impact Index and the Baltic Sea Pressure Index

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0. Preface

This report is the final report of the Theme 1 of the TAPAS project (agreement number - 07.0201/2015/717804/SUB/ENVC.2). The objective of the Theme 1 was to further develop the Baltic Sea Impact Index (BSII) which is tool for assessing cumulative pressures and impacts on the Baltic Seas marine environment. This report describes the protocol for using the BSII and improvements to the methodology as well as method and results of an expert survey to estimate habitat and species sensitivity to the BSII pressures.

1. Introduction

The Baltic Sea Pressure index (BSPI) and the Baltic Sea Impact index (BSII) are tools to estimate and spatially visualize cumulative pressures and impacts. They were first applied in the initial HELCOM holistic assessment of ecosystem health (HELCOM 2010a), building on concepts described by Halpern et al. (2008). The methods that were applied are described in HELCOM (2010b) and Korpinen et al. (2012). The concepts were subsequently developed further for the eastern parts of the North Sea by the HARMONY project (Andersen et al. 2013), which has developed a HARMONY Pressure & Impact Mapper software (Stock 2016). The same methodology has also been used in the Mediterranean and the Black Sea (Micheli et al. 2013).

In the first holistic assessment, the Baltic Sea Impact Index (BSII) was based on georeferenced data sets of human activities, pressures and ecosystem components, and on sensitivity estimates of ecosystem components (so-called sensitivity scores) that combine the pressure and ecosystem component layers. The scores estimate the potential impact of each assessed pressure on specific ecosystem components. The Baltic Sea Pressure Index (BSPI) assessed the anthropogenic pressures/human activities in the defined assessment units without including ecosystem components. However, it included a weighting component in order to grade the effect of the pressures on the ecosystem in a generalized perspective.

In the TAPAS project, the indices have been further developed for the use in the upcoming 'State of the Baltic Sea report' (HOLAS II). This has entailed re-evaluation of methods, several updates in the data preparation, index development, and alignment with the requirements of the MSFD. Also the habitat and species sensitivity estimates were improved.

Guidance for the tool development has been provided through expertise from the Contracting Parties through two HELCOM TAPAS workshops (HELCOM TAPAS Pressure Index WS 1-2016, HELCOM TAPAS Pressure Index WS 2-2016) and through HOLAS II project meetings (HOLAS II 4-2015, HOLAS II 5-2016, HOLAS II 6-2016. HELCOM HOD 51-2016 agreed in principle to use the method to calculate the Baltic Sea Impact Index (BSII) as presented in this report in HOLAS II. Outstanding issues, e.g. how to assess the impacts on ecosystem components, will still be tested and the final method to use in HOLAS II will be based on recommendations from workshops held under HELCOM SPICE project[1].

2. Methods

2.1 Calculation of the cumulative pressures and impacts

The BSII method relies on spatial data layers of ecosystem components (habitats, species) and anthropogenic pressures and links these together by so-called sensitivity scores, which transform the pressures to potential impacts on specific ecosystem components.

[1] SPICE is a HELCOM coordinated project that is co-financed by the EU under the call 'DG ENV/MSFD Second Cycle/2016' and will be implemented in 2017. Full name of the project is: Implementation and development of key components for the assessment of Status, Pressures and Impacts, and Social and Economic evaluation in the Baltic Sea marine region.

For the **BSII**, each pressure (D) – ecosystem component (e) pair within a 1 km × 1 km assessment unit is multiplied by their specific sensitivity score (μ) and the multiplied values within an ecosystem component (D×μ) are summed together (∑(D×μ)). If a certain ecosystem component does not exist in the assessed grid cell, the result is zero and does not affect the index score. A grid cell may include several ecosystem components and, in such a case, there are three options to calculate the index: a) as a sum (**Figure 1A**), b) as an average (**Figure 1B**), or c) select the ecosystem component receiving the highest cumulative impacts (Figure 1C).

A: sum of impacts

$$I_{\mathrm{sum}}(x,y)=\sum_{i=1}^{n}\sum_{j=1}^{m}D_i(x,y)e_j(x,y)\mu_{i,j}$$

B: mean of impacts

$$I_{Mean}(x,y)=\sum_{i=1}^{n}\sum_{j=1}^{m}\frac{1}{E_{Div}(x,y)}D_i(x,y)e_j(x,y)\mu_{i,j}$$

C: maximum impacts

$$I_{max}=\max(\sum_{i}^{n}D_i(x,y)e_j\mu_{i,j})$$

D: Pressure index:

$$S_{weighted}(x,y)=\sum_{i=1}^{n}(D_i(x,y)\frac{1}{m}\sum_{j=1}^{m}\mu_{i,j})$$

Figure 1. Formulas for calculating the Baltic Sea Impact Index (BSII) and the Baltic Sea Pressure Index (BSPI). Cumulative impacts (I), which form the basis of the BSII, were calculated on the basis of n pressures (D) and m ecosystem components (e) and weighted by the ecosystem's sensitivity to each pressure (μ). Impacts can be calculated in three alternative ways in the applied software. In addition to the option of summing information for all ecosystem component layers within a grid cell (as applied in the BSII; Formula A), the average level of impact across all ecosystem components can be used (Formula B), or the result for the maximally impacted ecosystem component can be shown (Formula C). Cumulative pressures (S), which form the basis of the BSPI, were calculated without considering the ecosystem components (Formula D).

Taking the sum of all impacted ecosystem components within an assessment unit (the 1 km × 1 km grid cell) will result in an increase of the index score in areas of high biodiversity. This outcome indicates potentially important areas under high threats. Using the average impact means that the end result does not indicate highly (or little) impacted ecosystem components, but shows the mean cumulative impact. The last outcome emphasizes the most sensitive ecosystem component per assessment unit and all the other information is omitted from the BSII result. The decision between the alternatives will be made for the HOLAS II context after testing them.

The **BSPI** method calculates only cumulative pressures whereas ecosystem components are not included in the calculation (Figure 1 D). The pressures are, however, weighted by average sensitivity scores from the BSII in order to get a more balanced view of their significance to the marine environment.

Both the indices are computed by the EcoImpactMapper software(Stock 2016). The software uses input data in csv-format, which are the center points of the assessment grid cells. Therefore, the raster maps of pressures and ecosystem components are first transformed to point data in csv format and, following the impact calculations results are transformed into raster format for visualization.

Expert survey to develop sensitivity scores

In the initial HOLAS (HELCOM 2010a) the sensitivity scores were estimated by expert judgment. In the HOLAS II assessment, increased emphasis will be given to wider expert coverage, improved guidance for setting the scores, as well as to evidence from scientific literature.

In the TAPAS project a specific task was to make a detailed questionnaire and circulate that among the Baltic Sea experts through the HELCOM contact points. The questionnaire (hereafter 'expert survey') was developed in Microsoft Excel together with a guidance document. In addition, the expert survey included guidance text in several steps and also comments for specific points. The expert survey is presented in **Annex 3**.

In the expert survey, 19 pressures and 40 ecosystem components were covered, resulting in a matrix of 750 potential pressure- and ecosystem-specific combinations (see **Annex 1 and 2** for the lists). In order to calculate as robust pressure- and ecosystem component specific sensitivity scores as possible, the questionnaire addressed the following 6 themes: (1) Tolerance/resistance, (2) Recoverability, (3) Sensitivity, (4) Impact distance, (5) Impact type and (6) Confidence.

For tolerance/resistance, participants in the survey had the following 3 options: High, Medium and Low (lethal). To support the participants, the survey included an explanatory text:

- Tolerance (resistance): How tolerant or resistant is the ecosystem to the human pressure? For example, for a pressure that has devastating effects on the ecosystem component in question, you should set the tolerance to a low value. If you should think that a specific human pressure has a relatively minor effect on this ecosystem component, you should set the tolerance to high. Factors to take into account when making your judgment are the typical intensity/level of the pressure when it occurs in the sea and typical biological effects (e.g. the number of trophic levels affected). You should not take into account if there actually is a spatial overlap between the pressure and the ecosystem component, since this will be included in other parts of the assessment.

For recoverability, the participants had the following 3 options: High, Medium and Low (> 10 years). To support the participants, the survey included an explanatory text:

- Recoverability: Reflects how long it takes for the ecosystem component to recover once the pressure ceases). The recoverability is estimated on a scale from immediate (high) to >10 years (low). Some human activities cause pressures which cease immediately after stopping the activity (such as noise from shipping), while some pressures may stay in the environment for a long time (such as contaminants and nutrients from pollution). However, independent of these differences, recovery times of the ecosystem components may differ. For instance, impacts on the species may last longer than the actual time the pressure exists in the sea.

For sensitivity, the participants had the following 3 options: High, Medium and Low. To support the participants, the survey included an explanatory text:

- Sensitivity: Although tolerance and recoverability affect sensitivity, other factors may also have an influence, and in some cases the different components of overall sensitivity may not be well known. Sensitivity is asked for as a complement to the above questions to ensure confidence in how the impact scores are calculated. In general, when rating tolerance, recoverability and sensitivity in the survey, you should imagine the human pressures as they typically occur in the study area. For instance, when replying for fish farms, imagine a typical fish farm, neither extremely big nor small. For commercial shipping, you should think of a busy, but not extraordinarily busy, shipping route. Also, assume that the stressor and the ecosystem occur together in the same place. As an example, if you know that an ecosystem component does not naturally occur close to any existing shipping routes, this does not mean that you should give it low vulnerability values. Instead, rate its vulnerability for the (hypothetical) case that the stressor and the ecosystem do occur in the same place, and the stressor is occurring at a typical intensity and frequency.

For impact distance, the participants were asked to answer the following question: "How far from the pressure/activity source will potential impacts on the ecosystem diminish to a negligible level, given its vulnerability?" The possible answers to this question were: (1) Local, (2) 1 km, (3) 5 km, (4) 10 km, (5) 20 km and (6) > 50 km.

For impact type, the participant were asked to identify which of the following 'impact distance types' (i.e. form of decay with increasing distance from the pressure source) in **Figure 2** could be assumed to be relevant for the pressure in question.

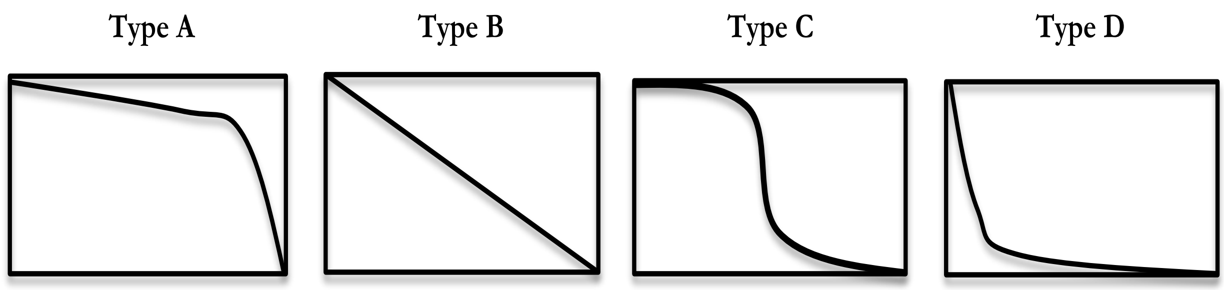


Figure 2. Impact types A, B, C and D. Type A describes a pressure that has a similar impact at most of its distribution range and then rapidly drops, type B describes a pressure that declines monotonously in strength from the source, type C describes a pressure having a somewhat limited decline within a given distance followed by a sharp decline, while type D describes a pressures which mostly has an strong impact in its vicinity.

For confidence, participants were asked to self-evaluate the confidence of their judgment, reflecting the information on which their answers were based. For example: (1) a low confidence should be assigned if limited or no empirical documentation (e.g. judgement is based on inference from other, similar ecosystem components/pressure types or from knowledge on the physiology and ecology of the species etc.). (2) a moderate confidence should be assigned if documentation is available, but results of different studies may be contradictory (e.g. including also grey literature with limited scope), and (3) a high confidence should only be given if documentation is available and with relatively high agreement among studies.

The survey replies were processed to medians and means. The 'sensitivity' field was used as the main basis for the final sensitivity scores, but the responses to 'tolerance' and 'recoverability' were analysed to find inconsistencies in the replies. In addition, the 'confidence' replies and the number of replies per score were used as to guide whether the sensitivity score was reliable.

2.2 Literature-based evidence to support the expert survey

The final TAPAS sensitivity scores are a combination of the results of the expert survey (see their processing above) and results of a literature review which was made under the BalticBOOST project (Korpinen et al. 2017). The BalticBOOST literature review of human activities evaluated impacts on benthic habitats and species and recovery times associated with those impacts. The information was given in a catalogue which lists all the literature references and their main results but also in more condensed form which can easily support overall conclusions of the sensitivity of benthic features to pressures. The BalticBOOST catalogue was used to support the development of sensitivity scores.

Although the approach was mainly limited to benthic habitats (**Table 1**), the literature review gave some support also to pelagic habitats, mammals, seabirds and fish.

Table 1. Benthic habitats defined for the Baltic Sea Impact Index in the HELCOM 2nd Holistic Assessment. The habitats are classified as broad habitats (EUNIS level 2) and habitat-forming species (EUNIS level 6)

Benthic habitat	**Characteristic species**
Broad-scale seabed habitats	
Infralittoral hard bottom	*Cladophora spp., Ceramium spp., Laminaria spp., Fucus spp., Furcellaria lumbricalis, Polysiphonia fucoides, Aegagrophila linnaei, Fontinalis spp.* Ascidiaceae, *Electra crustulenta, Flustra foliacea,* Balanidae, *Mytilus* spp.,*Modiolus modiolus*
Infralittoral sand	*Phragmites australis, Zostera marina, Potamogeton perfoliatus, Stuckenia pectinata, Tolypella nidifica, Chara aspera, Hediste diversicolor, Bathyporeia pilosa, Arenicola marina, Macoma balthica, Mya arenaria.*
Infralittoral mud	*Phragmites australis, Stuckenia pectinata, Potamogeton perfoliatus, Najas marina, Chara tomentosa, Hediste diversicolor, Gammarus spp.*
Circalittoral hard bottom	*Mytilus* spp., *Cordylophora caspia,* Hydrozoa, *Amphibalanus improvisus,* Bryozoa, Porifera, Hydrozoa
Circalittoral sand	*Mya arenaria, Macoma baltica, Arctica islandica, Pygospio elegans, Marenzelleria spp., Hediste diversicolor, Monoporeia affinis,* Chironomidae
Circalittoral mud	*Macoma balthica, Saduria entomon, Marenzelleria* spp, *Monoporeia affinis*
Habitat forming species	
Furcellaria lumbricalis	*Furcellaria lumbricalis*
Zostera marina	*Zostera marina*
Charophytes	*Charophytes (Chara spp., Tolypella spp, Nitella spp, Nitellopsis spp.)*
Mytilus edulis	*Mytilus edulis, M. trossulus*
Fucus sp.	*Fucus vesiculosus, Fucus radicans, Fucus serratus, Fucus evanescens*

The BalticBOOST report contained several useful elements for the development of the sensitivity scores. The following elements were used:

- Definitions of the three physical pressures;
- Descriptive conclusions of the impacts on different habitats;
- Ranking of human activities based on their impacts on different habitats;
- Numeric synthesis of the impacts and recoveries;

- Catalogue of the review results.

The sensitivity scores are given in categorical format:

- Not sensitive: the feature is not affected by the pressure.
- Low sensitivity: the feature is impacted but not easily (i.e. requiring higher pressure levels or longer exposure) and/or the recovery takes place within a year.
- Medium sensitivity: the feature is impacted already at medium pressure levels and/or the recovery takes at least a year.
- High sensitivity: the feature is impacted already at low pressure levels and/or the recovery lasts several years.

2.3 Impact chains from activities to pressures and impacts

The BSPI and BSII assessments use regionally approved lists of human activities, pressures and ecosystem components. The activities and pressures are based on the indicative lists given in the revised Annex III of the MSFD. The ecosystem components reflect key benthic and pelagic habitats in the Baltic Sea (on different levels of EUNIS biotope classification), habitats of functional importance (e.g. for reproduction) and species distribution models. The activities, pressures and ecosystem components are listed and defined in **Annex 1 and 2**.

Linkages between human activities, pressures and ecosystem components allow for back-tracking impacts to pressures and activities. These so-called linkage frameworks have been developed in several European research projects and compiled for this assessment. The linkages are referred to as impact chains (Knights et al. 2013) and they can be visualized to emphasize impacts either from a sector or ecosystem point of view. The HOLAS II linkage framework between activities and pressures is given in **Annex 6** and the links between pressures and ecosystem components (i.e. the impacts) are the sensitivity scores presented in this report (**Annex 5**).

2.4 Fact sheets of pressures and ecosystem components

Distribution and magnitude of human activities, pressures and ecosystem components have been made available through the HELCOM Data and Map Service (http://maps.helcom.fi/website/mapservice/index.html). Due to the complicated modifications of the data layers they are also presented as fact sheets where the main facts of the data source, development, etc. are described. These are presented in the metadata of the respective data layers in the HELCOM Data and Map Service.

2.5 Development of the pressure layers

Spatial layers of human activities, pressures and ecosystem components have been made available through the HELCOM Data and Map Service (http://maps.helcom.fi/website/mapservice/index.html). Processing of the data layers is presented in the metadata of the respective data layers in the HELCOM Data and Map Service.

Pressures used in the assessment of cumulative pressures and impacts are actually aggregated pressure types which comprise several subtypes of pressures and they are produced by several human activities. Therefore, development of a spatial data layer of these pressure types is a complicated process and can be only indicative of the actual level and extent of the pressure in the marine environment. The following paragraphs describe how the spatial pressure layers were produced.

Spatial extents. The pressures require a spatial extent. Many of the data layers in the assessment are based on the location of human activities but they do not indicate the spatial extent of pressures stemming from that activity. To represent the resulting pressures in a more realistic way, an expert survey by the TAPAS project, supported by a literature study by the BalticBOOST project[2], estimated the spatial extents of pressures from different sources. In addition, for pressures that attenuate at increasing distances from their source, the spatial representation of the pressures needs to incorporate the correct form of this decline. Information on attenuation was primarily taken from scientific literature but was also included in the TAPAS expert survey. The spatial extents and form of attenuation were assigned to the resulting spatial pressure layers on the basis of the expert survey and literature survey (see above) and are described in **Annex 1** and the pressure fact sheets.

Water depth and seabed exposure. The effects of water depth or seabed exposure on pressure intensity have not been included in previous assessments of cumulative impacts, even though they influence the pressure intensity in many cases. This does not apply to all pressure types, but has significant consequences on the extent on some pressures by avoiding over-estimation of their impacts in deep or exposed areas. The pressures affected by water depth are mainly resuspension (physical disturbance) caused by shipping and biological disturbance caused by human activities taking place on the surface. The pressures affected by the seabed exposure are the input of organic matter and physical disturbance (sedimentation). The Baltic-wide map on seabed exposure (Bekkby et al. 2008) were used to down-weight the pressure values in shallow exposed areas and overweight them in sheltered areas for these two pressure types. Simple attenuation curves were assigned to the pressures affected by the water depth. The approach was recently tested for the Finnish Archipelago Sea (Sahla 2015) and was further developed in TAPAS. The main purpose of including these extra factors was to avoid over-presenting impacts from some pressures on more exposed areas or deeper sea areas. The technical detailed are described in the pressure fact sheets and the **Annex 1**.

Temporal aspects. The pressure data layers need to encompass the specified assessment period (2011-2015) and, in addition, give a representative indication of the annual sum of the pressure in the assessment unit. The latter requirement was defined for each pressure so that they more accurately represent continuous, seasonally relevant or intermittent pressures. The simplest approach is to consider if there is additivity of the pressures over time; for pressures that last long (e.g. loss of a habitat) assessment values will be the accumulated value for all years during the entire assessment period (2011-2016). For more temporary pressures the pressure levels may be annual sums or annual averages which are then averaged over the years of the assessment period. For instance, summing of pressure magnitudes within a year can distinguish areas of continuous or intermittent pressures. These are described in the pressure fact sheets.

Also the ecosystem components – species or habitats – can be affected by temporal issues. For instance, seasons can affect the sensitivity of species and habitats:

- during the breeding time a species may be highly affected by pressures occurring near the breeding area, whereas the impact may be smaller during other times of year;
- annual vegetation in shallow areas may be more sensitive to pressures during the growth season than during the resting stage.

In the TAPAS, it was not, however, possible to discern the pressures to seasonal values, as some source data was given as annual data.

Balancing the pressure source data. The HELCOM BalticBOOST Workshop on Physical loss and damage to the seafloor (June 2016, Copenhagen) discussed the problem of unbalance in the pressure magnitude from

[2] BalticBOOST is a HELCOM coordinated project that was co-financed by the EU under the call 'DG ENV/MSFD Action Plans /2014' and implemented in 2015-2016. The full name of the project is: Baltic Sea project to boost regional coherence of marine strategies through improved data flow, assessments, and knowledge base for development of measures

different activities and the biases this may cause to a cumulative impacts assessment. For example, shipping causes a certain amount of resuspension of sediment (causing physical disturbance). According to the BSII method this activity is quantified on the basis of the ship traffic and the resulting pressure scale is normalized to 0-1 scale. The same pressure (physical disturbance) is also caused by dredging and the pressure scale is based on the amount of dredged material and then normalized to the 0-1 scale. As a result, both activities result in a pressure which is expressed on the same scale although in reality the magnitudes of the pressures are different (e.g. dredging causes much higher turbidity and sedimentation).

The development of pressure layers followed the method suggested by the TAPAS project and applied for the physical disturbance pressure by the BalticBOOST project (Korpinen et al. 2017). This is a three-step procedure:

- When aggregating spatial data sets, human activities causing the same pressure are ranked according to the magnitude of the pressure they are causing. This ranking was made for the two physical pressures on seabed on the basis of the literature review (Korpinen et al. 2017);
- The ranked activities (per pressure) are classified to 6 categories expressing the magnitude of the pressure. The categories are defined as percentages of the maximal occurring pressure;
- The percentages (0- <20%, 20- <40%, 40- <60%, 60- <80% and 80- 100%) are used as weights for each of the activities when shaping the pressure layers (0.2, 0.4, 0.6, 0.8 and 1.0).

The proposed approach increases the reliability of the BSII method. The BalticBOOST literature review gives a good basis for understanding the relative scales of pressures and their impacts from different activities taking place at the sea. These weights were applied to the physical disturbance data layers.

2.6 Testing the BSII in a case study

The HELCOM TAPAS project had the task to test the Baltic Sea Impact Index (BSII) in a case study. In this report, we present the testing results by focusing on benthic broad-scale habitats and the two pressures impacting it (physical loss and physical disturbance). More comprehensive testing was not possible due to the delayed data submission of HELCOM Contracting Parties. A complete BSII assessment was calculated after the testing in the SPICE project and published in the first version of the HELCOM holistic assessment (http://stateofthebalticsea.helcom.fi/cumulative-impacts/).

The two pressure layers and the eight benthic broad-scale habitat layers that were used in the testing in this project are described in **Annexes 1 and 2**. Moreover, the test area did not cover the entire Baltic Sea as the EMODnet broad-scale habitat layers were not yet available for the SW parts of the region in the testing phase of this project.

Updated sensitivity scores of broad-scale habitats to the two pressures were not yet available from the TAPAS expert survey or the BalticBOOST literature survey at the time of the case study but a set of estimates simplified from the application of the BSII in the initial holistic assessment (HELCOM 2010a) were used instead in order to test the tool. **Table 2** presents the interim sensitivity scores that were used. They were used in the scale from 0 to 4, which was the HOLAS I method. As physical loss represents an ultimate impact on a habitat, all the habitats were given highest sensitivity to that pressure.

Table 2. Interim sensitivity scores (0-4) for the eight broad-scale habitat types and two benthic physical pressures in the testing of the BSII tool. A higher score means a higher sensitivity and, hence, indicates that stronger impacts from the pressures are expected.

	Physical loss		Physical disturbance	
	Infralittoral	Circalittoral	Infralittoral	Circalittoral
mud	4	4	3	3
sand	4	4	3	3
mixed	4	4	2	2
hard	4	4	3	3

The data layers were prepared as described in **Annex 1** of this report, and in addition four of them were log-transformed in order to remove the dominance of a few high values. The four layers were shipping, bottom-trawling, dredging and disposal of dredged matter.

3. Results

3.1 Sensitivity scores from the expert survey

A total of 81 persons from 9 countries responded to the survey (**Table 3**). Based on the 81 replies received, we synthetized the results as outlined below and the summarized replies are given in **Annex 4**.

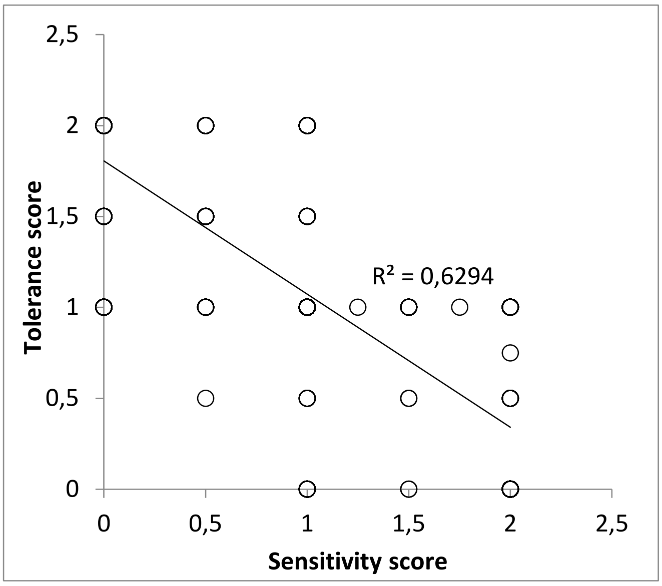
Table 3. Number of replies per HELCOM Contracting Parties and the HELCOM Secretariat.

Country	Number
Denmark	19
Estonia	0
Finland	11
Germany	17
Latvia	2
Lithuania	3
Poland	8
Russia	0
Sweden	21
EU – DG ENV	0
HELCOM Secretariat	0
Total	81

With regard to the theme “tolerance”, we calculated the number of replies, average values and medians. There is a large variation in the number of replies for each of the pressure- and ecosystem component specific combinations (range 1-35; mean 12.1; SD 6.1), which means that some of the combinations are based on very few responses. Some variability was also found within the responses: in summary, standard deviation of the responses around the mean ranged from 0 to 1, the average SD being 0.55 and its variability 0.19 (SD). The P x EC combinations with high SD (e.g. ≥1.0) can be regarded as less reliable as the ones with lower SD. **Table 4** lists the cases of high variability.

For the theme “recoverability”, we calculated the number of replies, average values and medians. Again, there was a large variation in the number of replies for each of the pressure- and ecosystem component specific combination (range 1-35; mean 11.8; SD 6.1). The within-responses variability was higher for this factor than for tolerance: mean 0.62 (±0.23 SD) and range from 0 to 1.41 in SD.

For the pressure- and ecosystem component specific sensitivity scores, we calculated the number of replies, average values and medians. Once again, there was a large variation in the number of replies for each of the pressure- and ecosystem component specific combinations (range 1-35; mean 11.4; SD 5.7). The within-response variability was also rather high for this factor: mean 0.62 (±0.20 SD) and range from 0 to 1.41 in SD.



We compared the sensitivity scores with the tolerance scores and recoverability scores with the aim to analyse whether the experts have understood the linkage between tolerance and sensitivity or recoverability and sensitivity in a coherent way. The best fit was found with the tolerance scores (R^2=0.63, **Figure 3**), whereas the correlation with the recoverability scores was poorer (0.20). We also correlated the sensitivity scores and average scores for each combination of pressure and ecosystem component, because the sensitivity was defined on th ebaiss of these two factors; the correlation coefficient was 0.51. Based on the results, we think that the factor 'sensitivity' may give more reliable estimates of the ecosystem component sensitivity than the factors 'tolerance' or 'recoverability' or their average. According to the definition of the factor 'sensitivity', it should include the aspects of both of the other two factors.

Figure 3. Correlation between the tolerance and sensitivity scores among all the pressure and ecosystem component responses. The data are the mean values of the expert responses.

For the theme "response type", we calculated the relative distribution for each of the four response types. We selected the type which received most responses, but in 29% of the cases several types received the same response rate (**Figure 4**). For instance, the types B and D were selected in 9% of the cases as equal response types; the type B being a declining linear response and D being a first steeply and then slowly declining response. Similarly, types A (first slowly and steeply declining) and D, were selected equally in 5% of the cases, types A and B in 4% of the cases and types B and C in 3% of the cases. The other cases were rarer, comprising the rest 6% of the cases. In the cases where majority of experts did not select a single response type, there is a need to find further support for the response type, e.g. from scientific literature.

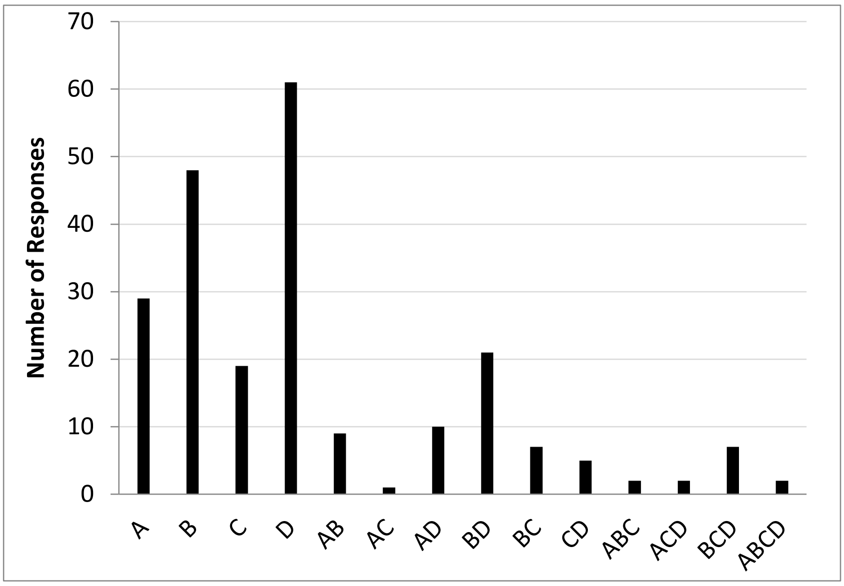


Figure 4. Count of Impact types for the 229 pressure –ecosystem component combinations. For example, A indicates combinations where only response type A was specified. ABC indicates combinations where response types A, B and C (but not D) were specified. See Figure 2 for definitions of the types.

Impact distances were asked in the survey for each P-EC combination and some values were given as alternatives (see Methods). The responses were calculated as mean values and medians. There were differences between the pressures in their impact distances, covering the entire range of the offered distances 0-50 km. Variability among the responses was measured by standard deviation which ranged between 0 and 28 km (the higher values indicating the variability around the high distance pressures). Generally, the resulting distance values are distinguishable between locally occurring pressures (such as physical disturbance or disturbance of species) and different types of pollution pressures (such as inputs of nutrients, noise and hazardous substances).

In regard to confidence, we calculated mean values. The mean confidence on the scale 1-4 was sufficient (2.1) with a standard deviation 0.5. The lowest confidence (1.2) was given to the pressure Input of radionuclides. Other low-confidence pressures were (<2.0): changes in hydrological conditions, inputs of other forms of energy, input of hazardous substances, input of litter, introduction of non-indigenous species and translocations, changes in climatic conditions, and acidification. The highest confidence was given to the pressure inputs of nutrients. Among the ecosystem components, the lowest and highest confidence, respectively, were given to 'Baltic esker islands' (1.8) and 'Oxygenated deep waters' (2.5). In general, the confidence among was ecosystem components was less variable than among pressures. When looking more closely, the lowest confidence (1.0) was given to responses of the habitat 'Submarine structures made by leaking gas' to radionuclides, climate change and acidification. The highest confidence (3.4) was given to responses of roach to nutrient inputs. As the variability of the confidence was also rather low (0.27-0.71 among ecosystem components; 0.19-0.50 among pressures), we conclude that the confidence was generally sufficient.

Compared to earlier studies, e.g. HELCOM HOLAS I (HELCOM 2010b, Korpinen et al. 2012), HARMONY (Andersen et al. 2013), and TACIA (Andersen et al. 2017), it is clear that the outcome of HELCOM TAPAS represents a big step forward toward setting of robust sensitivity scores. When scrutinizing the replies received – and focusing on the sensitivity scores rather than on tolerance and recoverability – it is clear that approximately 1/3 of pressure/ecosystem component combinations are very well covered, that another 1/3 are adequately covered and that the remaining 1/3 are poorly covered. **Table 4** shows those pressure – ecosystem component combinations which require closer investigation due to their (1) low number of replies, (2) poor confidence or (3) high variability among responses.

Table 4. Sensitivity scores requiring further support. Three criteria were used: low number of replies (generally >8); high variability of sensitivity score (STD ≥1.0) and low confidence estimate (<1.5).

Low number of replies
Inputs of energy to all habitats (benthic and pelagic) and habitat-forming species (low number of replies).
All pressures to the 'submarine structures made by leaking gases' (low number of replies).
Extraction of or injury to mammals to all habitats (benthic and pelagic), habitat-forming species (low number of replies) and fish (low number of replies).
Acidification to all ecosystem components (low number of replies).
Responses of 'Baltic esker islands' and 'Baltic Boreal islets' to most pressures except physical ones, nutrient inputs and input of heat (low number of replies).
High variability in sensitivity score
'Productive surface waters' to fishing mortality (high standard deviation: 1.0), mammal mortality (1.0).
'Circalittoral hard bottom' to fishing mortality (high standard deviation: 1.0)
'Submarine structures made by leaking gases' to changes in climatic conditions (high standard deviation: 1.4)
'Grey seal haul-outs' to acidification (high standard deviation: 1.4)
'Harbour seal haul-outs' to acidification (high standard deviation: 1.4)
'Furcellaria lumbricalis', 'Charophytes', 'Productive surface waters' to extraction of /injury to mammals (high standard deviation: 1.2, 1.2 and 1.0, respectively)
'Baltic esker islands' and 'Boreal Baltic islets' to changes in climatic conditions (high standard deviation: 1.2 to both)
'Bird migration routes', 'Grey seal abundance', 'Harbour seal abundance', 'Estuaries', 'Recruitment areas of pikeperch' and 'Recruitment areas of roach' to acidification (high standard deviation: 1.2,1.2, 1.2, 1.0 and 1.0, respectively)
'Grey seal abundance' and 'Harbour seal abundance' to inputs of radionuclides (high standard deviation: 1.0 for both)
Low confidence
'Submarine structures made by leaking gases' to changes in hydrological conditions (confidence 1.3), input of hazardous substances (1.3), oil spills (1.3), input of litter (1.2), and acidification (1.0).
'Baltic esker islands' to input of continuous sound (confidence 1.4), other forms of energy (1.4), and input of litter (1.4)
'Boreal Baltic islets' to input of litter (confidence 1.3)
'Mudflats and sandflats' to input of hazardous substances (1.4), and changes in climatic conditions (1.3)
'Estuaries to input of hazardous substances (1.4), and changes in climatic conditions (1.0)
Introduction of radionuclides to 34 of 40 the ecosystem components (confidence ranging 1.0-1.4)
'Breeding seabird colonies' to input of litter (confidence 1.4)
'Grey seal haul-outs' and 'Harbour seal haul-outs' to changes in climatic conditions (confidence 1.4)
'Ringed seal distribution' to acidification (confidence 1.4)
Introduction of NIS to 'Distribution of harbour porpoise' to (confidence 1.2), 'Harbour seal haul-outs' (1.3), 'Grey seal haul-outs' (1.3), 'Migration routes for birds' (1.2), 'Breeding seabirds colonies' (1.4), 'Wintering seabirds (1.2), and 'Submarine structures made by leaking gas' (1.4)

3.2 Literature-based development of sensitivity scores

Physical loss

It could be argued that use of the concept of sensitivity is not appropriate for the physical loss pressure. Physical loss is an ultimate impact on seabed which is caused by activities burying or changing the seabed to another type or filling it as terrestrial land. The definition given in the COM DEC 477/2010/EU (revised) uses a recovery time of 12 years to define this (see the BalticBOOST report for more practical definition, Korpinen et al. 2017).

However, the BSII tool requires a sensitivity score also for the physical loss pressure and, as a technical solution, it is suggested that all the habitats are given the sensitivity 'High' in the BSII tool. For species, the physical loss can be defined through the expert survey.

Physical disturbance

As the physical disturbance is caused by multiple human activities exerting different levels of pressure, the sensitivity scores are developed according to the human activities causing high impacts. This is justified because the other activities are down-weighted when producing the aggregated pressure data layers.

According to the ranking of human activities in the report by the BalticBOOST project (Korpinen et al. 2017), the most impacting human activities causing physical disturbance (in most of the benthic habitats) are: capital dredging, maintenance dredging, disposal of dredged material and aggregate extraction. These are the activities which impacts are especially considered for the benthic habitats. **Table 5** presents a summary of the impacts and recovery times and the proposed sensitivity category for each of the listed habitats.

Table 5. Sensitivity scores of benthic habitats to physical disturbance pressure. The sensitivity is estimated on the basis of high-impacting activities by the literature review of the impacts and recovery times.

Benthic habitat	Reported impacts	Recovery	Sensitivity category	Justification references
Broad-scale seabed habitats				
Infralittoral hard bottom	Strong siltation impacts.	>4 years, depends on shore exposure	High sensitivity	Essink 1999, Vahteri & Vuorinen 2001, Oulasvirta & Leinikki 2003, Kotta et al. 2009
Infralittoral sand	Intermediate-high siltation impacts on eelgrass	>2-6 years	High sensitivity	Oulasvirta & Leinikki 2003, Erftemeijer et al. 2006
Infralittoral mud	Vegetation and fish spawning highly impacted. Impacts not as high as on hard bottoms.	4-6 years	High sensitivity	Oulasvirta & Leinikki 2003, Eriksson et al. 2004, Sandström et al. 2005, Munsterhjelm 2005, Torn et al. 2010, Vatanen et al. 2012
Circalittoral hard bottom	Sedimentation higher due to less wave energy and limits settlement of sessile fauna.		High sensitivity	Essink 1999
Circalittoral sand	Macrofauna effects after modification are strong and recovery is long.	0.5-4 years	High sensitivity	Newell et al. 1998, Boyd et al. 2000, Dalfsen & Essink 2001, Boyd et al. 2003, Barrio Frojan et al. 2008, Frenzel et al. 2009, Manso et al. 2010, Vatanen et al. 2012, Wan Hussin et al. 2012

Circalittoral mud	Intermediate siltation impacts. Altered size distribution (juveniles die). Mortality takes place but recovery is rather fast.	typically 2.5-6 years	Intermediate sensitivity	Essink 1999, Orviku et al. 2008, Powilleit et al 2009, Vatanen et al. 2012
Habitat forming species				
Furcellaria lumbricalis	Sedimentation effects are high.		High sensitivity	Eriksson & Johansson 2005
Zostera marina	Sedimentation effects are high.	4-6 years	High sensitivity	Oulasvirta & Leinikki 2003, Erftemeijer et al. 2006, Munkes et al. 2015
Charophytes	Sedimentation and altered wave energy impact highly.		High sensitivity	Eriksson et al. 2004, Munsterhjelm 2005, Sandström et al. 2005, Torn et al. 2010
Mytilus edulis	Sedimentation effects are high.		High sensitivity	Kotta et al. 2009
Fucus sp.	No colonization and 80% loss of coverage at impact zone.	>4 years	High sensitivity	Bonsdorff 1980, Bonsdorff et al. 1986, Eriksson & Johansson 2005, Vatanen et al. 2012, Syväranta et al. 2013, Syväranta & Leinikki 2015

Hydrographical changes

Physical impacts of hydrographical changes were estimated for the broad-habitat types only. Based on a review of effects of coastal structures (e.g. piers, groynes, etc.) and another review of offshore installations, **Table 6** proposes sensitivity scores ranging from low to high. The highest sensitivity is estimated for shallow (infralittoral) hard bottoms. Other infralittoral habitats were estimated as intermediately sensitive and the deeper habitats as 'low'.

Table 6. Sensitivity scores of benthic habitats to the pressure 'Hydrographical changes'. The sensitivity is estimated on the basis of high-impacting activities by the literature review of the impacts and recovery times.

Benthic habitat	Reported impacts	Sensitivity category	Justification references
Broad-scale seabed habitats			
Infralittoral hard bottom	Accumulation of finer sediments to landward side of coastal structures -> high biological impact on sessile species.	High	Martin et al. 2005
Infralittoral sand	Accumulation of finer sediments to landward side of coastal structures -> biological change. Abrasion around an installation changes seabed morphology and substrate.	Intermediate	Martin et al. 2005, Eastwood et al. 2007

Infralittoral mud	Accumulation of finer sediments to landward side of coastal structures -> biological change. Abrasion around an installation changes seabed morphology and substrate.	Intermediate	Martin et al. 2005, Eastwood et al. 2007
Circalittoral hard bottom	No information		
Circalittoral sand	Abrasion around an installation changes seabed morphology and substrate (smaller at greater depths)	Low	Eastwood et al. 2007
Circalittoral mud	Abrasion around an installation changes seabed morphology and substrate (smaller at greater depths).	Low	Eastwood et al. 2007
Habitat forming species			
Furcellaria lumbricalis	No information		
Zostera marina	No information		
Charophytes	No information		
Mytilus edulis	No information		
Fucus sp.	No information		

Literature-based sensitivity scores for other pressures

The HELCOM BalticBOOST project did not specifically focus on other pressures than the three physical pressures, but some information was compiled and this is used to develop sensitivity scores in **Table 7** (benthic habitats) and **Table 8** (species).

Table 7. Sensitivity scores of benthic habitats to other pressure types. The sensitivity is estimated on the basis of high-impacting activities by the literature review of the impacts and recovery times.

	Infralittoral hard bottom	Infralittoral sand	Infralittoral mud	Circalittoral hard bottom	Circalittoral sand	Circalittoral mud
Input of organic matter	High (1, 9)	High (1, 9)	High (1,8, 9)	High (1, 9)	High (1, 9)	High (1,8, 9)
Input of hazardous substances	High(2)	High(2,10)	High(2,5,10)	High(2)	High(2,10)	High(2,10)
Input of nutrients	Inter-mediate(3)	Inter-mediate(3)	High(3, 4)	Inter-mediate(3)	Inter-mediate(3)	Inter-mediate(3)
Input of heat	Inter-mediate(6)	Inter-mediate(6)	Inter-mediate(6)	Inter-mediate(6)	Inter-mediate(6)	Inter-mediate(6)
Inputs of radioactive substances	Low (7)					
Input of impulsive noise	Intermediate (12)	Intermediate (12)	Intermediate (12)	Intermediate (12)	Intermediate (12)	Intermediate (12)
Input of continuous noise	Low (12)	Low (12)	Low (12)	Low (12)	Low (12)	Low (12)

Input of electromagnetism	Low [11,12]	Low [11,12]	Low [11,12]	Low [11,12]	Low [11,12]	Low [11,12]

(1) Recovery time of zoobenthos is 5-10 years (Bonsdorf et al. 1986).

(2) Recovery time of zoobenthos is 8- >10 years (Bonsdorf et al. 1986).

(3) Recovery time of zoobenthos is ca 5 years (Bonsdorf et al. 1986)

(4) Macroalgal mats and anoxia cause mass mortality (Ellis et al. 2000)

(5) 30-40% zoobenthos density reduction (Ellis et al. 2000)

(6) Increased water temperature by 2-4 C degrees (nuclear) or 1 C degree (coal plant) in the summer until 1-1.5 km distance (Ilus et al. 1986, Karppinen & Vatanen 2013); 5-9 C degree increase at 200 m distance outside a coal plant (Karppinen et al. 2011).

(7) Increased radioactivity at 10 km distance (Ilus et al. 1986)

(8) No recovery of zoobenthic community after 8 years of cessation of a fish farm in a sheltered bay (Kraufvelin et al. 2001)

(9) 10-fold periphyton biomass at 500 m distance from a fish farm (Leskinen et al. 1986)

(10) Near oil platforms sensitive species are progressively substituted by indifferent, tolerant and second- and first-order opportunistic species (Muxika et al. 2005, Terlizzi et al. 2008)

(11) Electromagnetic effects may take place, they are stronger for cables with electrodes and weaker for bipolar cables (Andrulewicz et al. 2003)

(12) Review of impacts of wind farms under construction and in operation (Bergström et al. 2014)

Table 8. Sensitivity scores of species groups to other pressure types. The sensitivity is estimated on the basis of high-impacting activities by the literature review of the impacts and recovery times.

	Seals	Porpoise	Fish	Seabirds
Input of impulsive noise	High [3]	High [3]	High [1,2]	
Input of continuous noise	Low [3]	Intermediate [3]	Low [1,2,3]	
Input of electromagnetism	Low [3,4,6]	Low [3,4,6]	Low [3,4,6]	
Disturbance of species: collision				Intermediate [5]

(1) Construction of wind farms (pile driving): fish mortality, hearing loss, behavioural changes upto 70 km (Andersson 2011)

(2) Operational wind farm: behavioural changes for several fish species; distance <1 km for eel and salmon, >16 km for herring and cod (Andersson 2011).

(3) Review of impacts of wind farms under construction and in operation (Bergström et al. 2014)

(4) Electromagnetic effects may take place, they are stronger for cables with electrodes and weaker for bipolar cables (Andrulewicz et al. 2003)

(5) Gill AB (2005) Offshore renewable energy: ecological implications of generating electricity in the coastal zone. Journal of Applied Ecology 42, 605–615

(6) Wilhelmsson, D., Malm, T., Thompson, R., Tchou, J., Sarantakos, G., McCormick, N., Luitjens, S., Gullström, M., Patterson Edwards, J.K., Amir, O. and Dubi, A. (eds.) 2010. Greening Blue Energy: Identifying and managing the biodiversity risks and opportunities of offshore renewable energy. Gland, Switzerland: IUCN. ISBN: 978-2-8317-1241. 102pp.

3.4 Final sensitivity scores for the BSII

The two approaches to develop sensitivity scores for habitats and species (i.e. the so-called ecosystem components) were combined in order to arrive at more reliable and evidence-based sensitivity scores. The evaluation was first made for the literature-based scores from the BalticBOOST project (**Tables 5-8**) against the expert-based scores. The expert-based scores range from 0 (low sensitivity) to 1.0 (intermediate sensitivity) and 2.0 (high sensitivity). Secondly, we examined those expert-based scores which were found to be weak (i.e. few or widely varying responses or low confidence scores) (see **Table 4**). In this section, we evaluate the scores and justify the decisions. Final proposed sensitivities are given in **Annex 5**.

The literature review suggested that all the sensitivity scores for the '**physical loss**' pressure are set to 'High' to benthic and pelagic habitats and that the expert-based scores can be used in case of species. An evaluation of the expert-based scores for physical loss shows that the mean score for benthic habitats is 1.83 of the maximum 2.0. This shows that also the experts considered the benthic habitats to be highly sensitive to physical loss and the literature-based 'High sensitivity' can be selected. For the two pelagic habitats, the expert survey gives the scores 0.4 and 0.9. As the physical loss pressure is by definition a benthic pressure, these low scores seem to be correct and no literature evidence is available to argue otherwise. Demersal spawning areas of fish (roach, pike and pikeperch) received scores 1.3-1.4 which is surprisingly low if compared to the fact that physical loss removes the benthic vegetation where these species spawn. Therefore it is suggested that the 'High sensitivity' is given also for these spawning habitats. Mammals, seabirds and pelagic fish received a mean score 0.86 (range 0.5-1.2) which is of the same magnitude as the scores for pelagic habitats. For these species it is proposed that the expert-based scores are retained.

The pressure '**physical disturbance on seabed**' was estimated – on the basis of the literature – as highly impacting and the sensitivity scores were almost entirely 'high'. In the expert survey, the resulting scores were quite variable for different types of habitats: the average score 1.17 (range 1.0-1.3) for all broad-scale habitats, 1.76 (range 1.6-1.9) for all habitat-forming species and 1.56 (range 1.2-1.7) for all the Natura 2000 habitats (if 'submarine structures made by leaking gases' is omitted, the mean is 1.6 (range 1.5-1.7). The results clearly indicate that the more there are biological elements in the habitat classification, the more sensitive the habitat is seen by the experts. Scientifically this is correct and should somehow be visible in the sensitivity scores. In the literature-based scores for benthic habitats (**Tables 5-6**) this difference was not visible because it was considered that the broad-scale habitats include all the biotic and abiotic features. If we had several EUNIS 6 –level biotope maps available for the Baltic Sea (in addition to the habitat-forming species), it would be sufficient to give lower sensitivity scores for the broad-scale habitats. However, in the current situation, there are only five EUNIS 6 –level maps for the entire Baltic Sea and therefore the broad-scale habitats should reflect also the biological features. Therefore we suggest that the sensitivity difference between the broad-scale and more detailed habitats should not be too big but some difference can be indicated as the scores will use decimal numeric values.

Sensitivity of pelagic habitats (surface and deep) to physical disturbance was scored as 1.0 and 0.7, respectively, indicating intermediate sensitivity. This is in line with the literature review where it was found that the recovery after siltation and consequent turbidity is fast and therefore the sensitivity cannot be considered more than 'intermediate' (i.e. score 1.0). Sensitivity of mammals, fish and seabirds in the expert survey ranged between 0.5 and 1.3 (mean 0.81), likely indicating that the highly mobile species are only indirectly affected by seabed disturbance.

Changes in hydrological conditions were not estimated as serious in the survey as the other two physical pressures. The broad-scale habitats had sensitivity scores ranging between 0.9 and 1.4 (mean 1.17), indicating intermediate impacts, which is partly in line with the literature review, where deeper habitats were estimated as 'low sensitivity' and infralittoral habitats as 'intermediate'. It is proposed that the circalittoral habitats would have a slightly lower sensitivity than the infralittoral ones and the infralittoral hard bottoms would have highest sensitivity (see **Table 6**). Pelagic habitats in surface and deep had sensitivity scores 0.6 and 1.3, Natura 2000 habitats ranged between 1.1 and 1.8 (mean 1.4), habitat-forming species between 1.3-1.7 (mean 1.54) and the mobile species between 0.4 and 1.2 (mean 0.72).

Sensitivity to **input of continuous noise** was estimated by the expert survey highest to the marine mammals (mean 1.52), and especially harbor porpoise (1.7). Fish and seabird sensitivities ranged between 0.2-0.8 (mean 0.52) and all habitats between 0-1.0 (mean 0.39). This is in line with the literature-based estimates, which suggested low sensitivity to all habitats, fish and seals and intermediate sensitivity for harbor porpoise (see **Tables 7-8**). The **input of impulsive noise** was rated rather similarly, as marine mammal sensitivity scores ranged between 1.5-1.9 (mean 1.62, harbor porpoise getting 1.9), fish and seabirds getting the scores 0.7-1.1 (mean 0.92) and all habitats between 0 and 1.0 (mean 0.41). These results are in contrast with the literature, where intermediate-high sensitivity was suggested for all the ecosystem components (**Tables 7-8**). However, the literature was not referring to real measurements but assumptions and therefore the expert survey results are suggested to be retained. Sensitivity of all ecosystem components to **electromagnetism** scored between 0 and 1.0 (mean 0.54). This is in line with the literature review which estimated low sensitivity to all ecosystem components.

The expert survey resulted in variable sensitivity to **input of heat**. Pelagic and benthic broad-scale habitats scored between 0.6 and 1.3 (mean 0.96), habitat-forming species scored between 0.9-1.6 (mean 1.3), Natura 2000 habitats between 0.9 and 1.7 (mean 1.11), fish between 0.3-0.8 (mean 0.56), seabirds between 0.3-0.6 (mean 0.4) and marine mammals between 0.2 and 0.6 (mean 0.36). Literature-based scores were estimated only for broad-scale habitats which all scored as ‘intermediate’. We suggest following the expert-based sensitivity scores.

Sensitivities against **input of hazardous substances** depended on the ecosystem component. Pelagic and benthic broad-scale habitats ranged between 0.9-1.2 (mean 0.99), habitat-forming species ranged between 0.8-1.1 (mean 0.92), Natura 2000 habitats had sensitivities between 0.6 and 1.2 (mean 0.83), seabirds and marine mammals ranged between 1.2 and 1.6 (mean 1.44) and fish between 0.4 and 0.9 (mean 0.62). The literature-based estimates were available only for sediment contamination which was considered as highly impacting for zoobenthos. This seems to be in contrast with the expert results which consider benthic habitats to be only intermediately sensitive. The difference may arise from the very high variability of substances and pollution levels; highly contaminated sediments may cause acute mortality whereas slow accumulation is only a problem for long-living predators. There seemed to be also high uncertainty among experts of these effects on habitats (and associated species) which is visible in Table 4. Our suggestion is that we use precautionary approach and score all ecosystem components as highly sensitive, but still give the score 2.0 only to seals and porpoise, while seabirds score 1.8, fish score 1.6 and all the habitats score 1.5.

Sensitivity to **input of nutrients** is probably best known in the Baltic Sea. Pelagic surface and deep habitats scored 1.5 and 1.8, respectively and the benthic broad-scale habitats scored between 1.2-1.3. Of the habitat-forming species, blue mussels scored only 0.9 whereas the plants scored between 1.3 and 1.9. Natura 2000 habitats scored between 1.2 and 1.6 (mean 1.4) and seabirds and mammals between 0.2 and 0.5. Among the fish, the deep-water and vegetation spawners scored high (1.3-1.7) whereas other fish were estimated to have rather low sensitivity (0.5-0.7). According to our scarce literature information, benthic broad-scale habitats were mostly scored as ‘intermediately sensitive’, which is in line with the expert survey. Knowing that there is high expertise in eutrophication impacts in the Baltic Sea science community, we suggest following the expert survey results for this pressure.

Input of radionuclides was not considered as highly impacting in the survey, as the expert scores ranged among all the ecosystem components only between 0 and 1.2 (mean 0.44). In the literature review there was only a single reference which indicated intermediate sensitivity for broad-scale habitats. We suggest following the results of the expert survey.

Sensitivity of broad-scale habitats to **oil slicks and spills** was estimated to range between 0.9 and 1.7 (mean 1.28) and the highest sensitivity was estimated for infralittoral hard bottoms. Habitat-forming species scored between 1.4 and 1.6 , Natura 2000 habitats between 1.5-1.9, fish between 0.5 and 1.7 (higher values for vegetation spawners), seabirds between 1.9-2.0 and marine mammals between 1.3 and 1.6. The scores showed a rather clear pattern for higher sensitivity in hard bottoms, reefs and vegetation and very high and obvious sensitivity of seabirds. No literature information was available through the review.

The expert survey showed low sensitivity of most of the ecosystem components to **input of litter**. The exceptions to this were the seabirds and marine mammals, which scored between 0.9-1.2, whereas the other ecosystem components scored between 0.1 and 0.8 (mean 0.42). No literature information was available through the review.

Sensitivity to **input of organic matter** was relatively clear 'intermediate' to the broad-scale habitats, Natura 2000 habitats, fish spawning habitats and habitat-forming species (0.8-1.4, mean 1.11). Marine mammals, seabirds and fish scored only 0.5 in average (0.3-1.1). According to the literature survey, organic enrichment has higher impacts and longer recovery times in case of benthic habitats than what is estimated by the expert survey (see **Table 7**). Therefore it is suggested that the sensitivity scores of all the benthic habitats is increased by 0.5 in relation to the expert-given score (now ranging between 1.3-1.9).

Marine mammals and seabirds were estimated to be sensitive to **human disturbance** (1.0-1.8, mean 1.36). Fish had clearly lower scores (0.4-1.3, mean 0.81) and the habitats were estimated between 0.2-1.2 (mean 0.67). No literature information was available through the review.

Sensitivity of fish to **fish extraction** was estimated to score 1.57 in average (1.2-2.0). Marine mammals and seabirds scored to this pressure – being indirectly impacted by decreased prey – between 0.7 and 1.5 (mean 1.13). Habitats scored between 0.3 and 1.1 (mean 0.74). No literature information was available through the review.

Extraction of mammals and seabirds (i.e. hunting, predator control and bycatch) was estimated to score 1.8 in average (1.9-2.0). Sensitivity of fish to this pressure was obviously low (0-0.7, mean 0.29). Habitats scored between 0.2 and 1.5 (mean 0.7). No literature information was available through the review.

Sensitivity of ecosystem components to **introduction of non-indigenous species and translocations of native species** was generally scored in the survey as 'intermediate' (range 0.3-1.4, mean 0.88). Pelagic and benthic habitats as well as Natura 2000 habitats were estimated as more sensitive (mean 1.04, range 0.7-1.4) than the mobile species (range 0.4-1.1, mean 0.69). This is rather obvious as most of the NIS are small and are found to affect invertebrate communities rather than larger species. However, it is also clear that the experts did not consider the terrestrial NIS (American mink and raccoon dog) which have heavy impacts on seabird populations. In the HELCOM HOLAS II, the terrestrial NIS are not part of the impact assessment and therefore it is not necessary to change the seabird sensitivity score, but this should be kept in mind in descriptive assessment of NIS. No literature information was available through the review.

Sensitivity of the Baltic Sea habitats and species to **changes in climatic conditions** was estimated in the expert survey as 'intermediate' (range 0.5-1.7, mean 1.01). The highest sensitivity (1.7) was estimated for ringed seal distribution and deep water conditions, which are both well-known phenomenon in the region. The lowest sensitivity (0.3-0.5) was estimated for freshwater fish species living in the coastal waters, where salinity is expected to decrease. The other climate-related pressure **acidification**, had higher variability in the responses (0.3-2.0, mean 1.02). The highest sensitivity was generally given to habitats where there are sessile species (e.g. submarine structures made by leaking gases, infralittoral hard bottoms, esker islands, boral Baltic islets), but this pattern was not consistent. This pressure was among the ones, where low confidence and low number of replies was highlighted in **Table 4**. No literature information was available through the review.

Table 9. Evaluation of sensitivity scores requiring further support.

Sensitivity scores with potential need for improvement	**Action taken**
Input of other forms of energy (e.g. electromagnetism) - low number of replies in all habitats (benthic and pelagic) and habitat-forming species - low confidence for Baltic esker islands.	As confidence was generally high and variability among the replies low, the expert survey results were retained.
‘Submarine structures made by leaking gases’: - low number of replies in all the pressures; - high standard deviation against changes in climatic conditions; - low confidence for changes in hydrological conditions, input of hazardous substances, oil spills, input of litter, Introduction of NIS and acidification.	Input of hazardous substances: sensitivity increased to 1.5; Input of organic matter: sensitivity increased to 1.6; In all the other pressures: the mean score was in line with the other sensitivity scores.
Extraction of or injury to mammals: - low number of replies for all habitats (benthic and pelagic), habitat-forming species and fish; - high standard deviation for ‘productive surface waters’, ‘Furcellaria lumbricalis’, ‘charophytes’,;	Requires further support.
Acidification: - low number of replies in all ecosystem components; - high standard deviation for ‘grey seal haul-outs’, ‘harbour seal haul-outs’, ‘bird migration routes’, ‘grey seal abundance’, ‘harbour seal abundance’, ‘estuaries’, ‘recruitment areas of pikeperch’ and ‘recruitment areas of roach’; - low confidence for ‘ringed seal distribution’.	Requires further support.
‘Baltic esker islands’: - low number of replies in most pressures except physical ones, nutrient inputs and input of heat; - high standard deviation in changes in climatic conditions; - low confidence for input of continuous sound	Input of hazardous substances: sensitivity increased to 1.5; Input of organic matter: sensitivity increased to 1.6; Input of continuous sound: Requires further support; Changes in climatic conditions: Requires further support; Other pressures in line with the other Natura 2000 habitats and hence scores were retained.
‘Baltic Boreal islets’: - low number of replies in most pressures except physical ones, nutrient inputs and input of heat; - high standard deviation in changes in climatic conditions; - low confidence for input of litter	Input of hazardous substances: sensitivity increased to 1.5; Input of organic matter: sensitivity increased to 1.6; Input of litter: Requires further support; Changes in climatic conditions: Requires further support.

	Other pressures in line with the other Natura 2000 habitats and hence scores were retained.
Fishing mortality: - high standard deviation in 'productive surface waters' and 'circalittoral hard bottom'.	Sensitivity scores in line with the other habitats scores; expert scores retained.
Introduction of radionuclides - low confidence in 34 of 40 the ecosystem components; - high standard deviation in 'grey seal abundance' and 'harbour seal abundance'	Requires further support.
'Mudflats and sandflats' : - high standard deviation in input of hazardous substances and changes in climatic conditions.	Input of hazardous substances: sensitivity increased to 1.5; Changes in climatic conditions: Requires further support
'Estuaries': - low confidence for input of hazardous substances and changes in climatic conditions.	Input of hazardous substances: sensitivity increased to 1.5; Changes in climatic conditions: Requires further support
'Breeding seabird colonies': - low confidence for input of litter	The sensitivity was in line with the other litter-related scores; expert scores retained.
'Grey seal haul-outs' and 'Harbour seal haul-outs': - low confidence in changes in climatic conditions	Requires further support
Introduction of NIS: - low confidence in 'Distribution of harbour porpoise', 'Harbour seal haul-outs', 'Grey seal haul-outs', 'Migration routes for birds' , 'Breeding seabirds colonies', 'Wintering seabirds'.	Requires further support

3.5 Test results of the BSII assessment

Figure 5 presents the results of the test run. As the test run included only one layer of ecosystem components (i.e. benthic habitats), the interpretability is straightforward and can only be attributed to pressure intensity or habitat sensitivity. In the full-fledged BSII with more ecosystem layers, the ecosystem diversity will also be a factor in the result.

The Baltic-wide result map does not allow inspection of small-scale impacts (such as dredging) and therefore **Figures 6-8** present a closer look at the area. In these results, the areas outside Helsinki, Tallinn and Karlskrona are more clearly visible because of, e.g. concentrated shipping and dredging activities in harbours. In **Figure 8** it is also visible how data gaps in inner coastal bays can affect the outcome (e.g. the effects outside the city of Greifswald are not visible).

The index results have not been validated with respect to scale, in order to show results at an ecologically meaningful scale. This could potentially be tested by comparing with the results of the HOLAS II integrated biodiversity assessment or in coastal areas with EU WFD results.

Figure 5. Cumulative impacts on benthic broad-scale habitats at Baltic Sea scale according to the pilot study, based on data available by August 2016 (all of the Baltic Sea will be covered in HOLAS II).

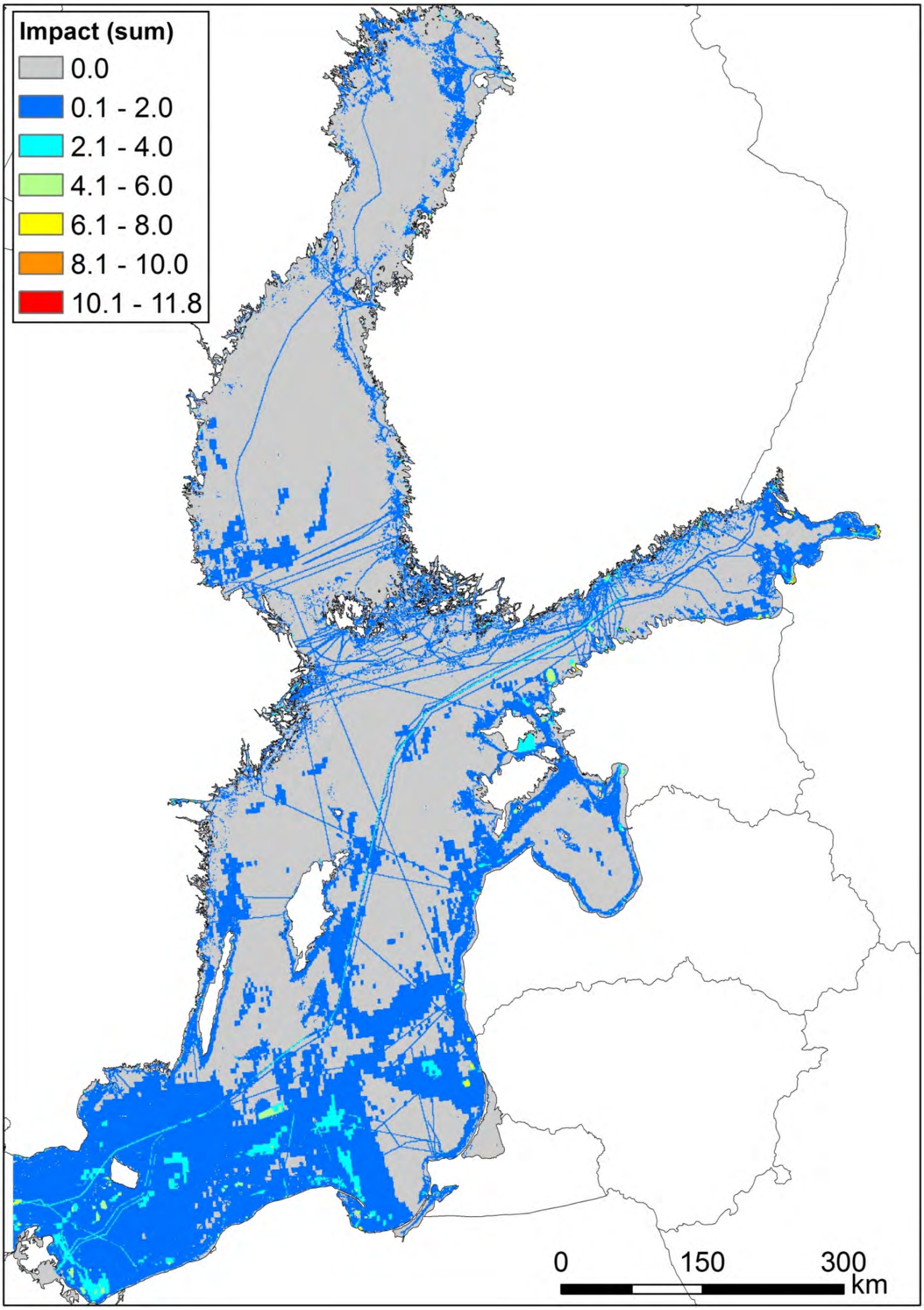


Figure 6. Cumulative impacts on benthic broad-scale habitats in the central Gulf of Finland.

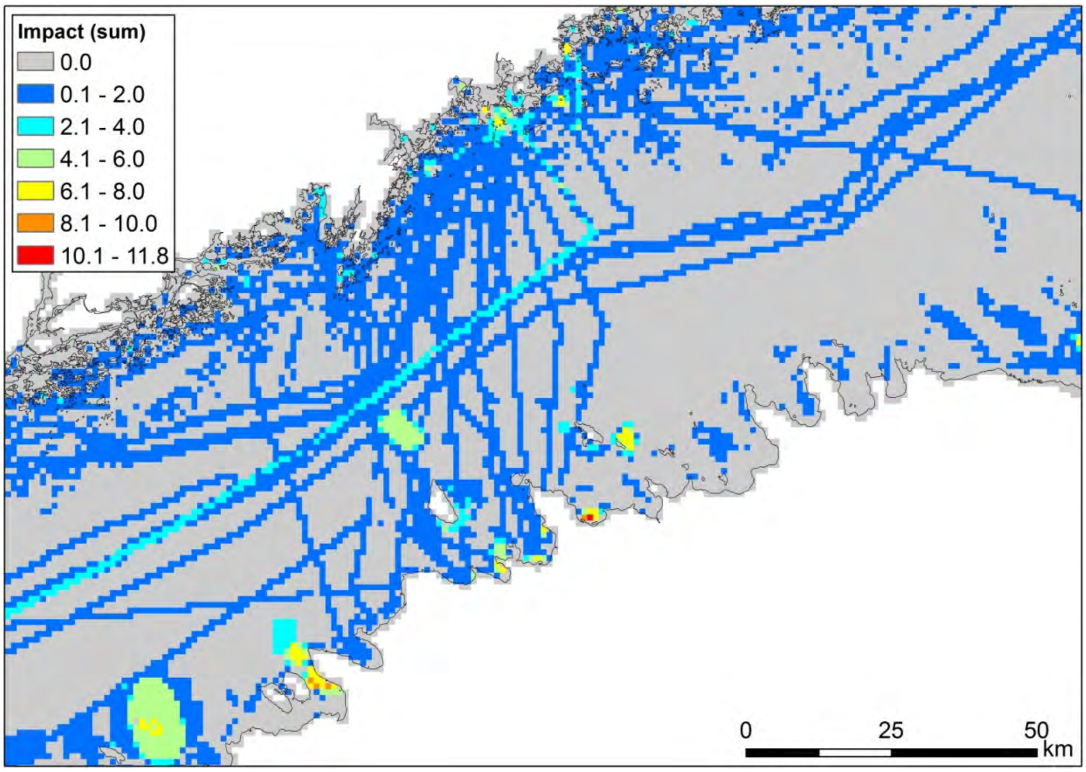


Figure 7. Cumulative impacts on benthic broad-scale habitats in the Hanö Bay.

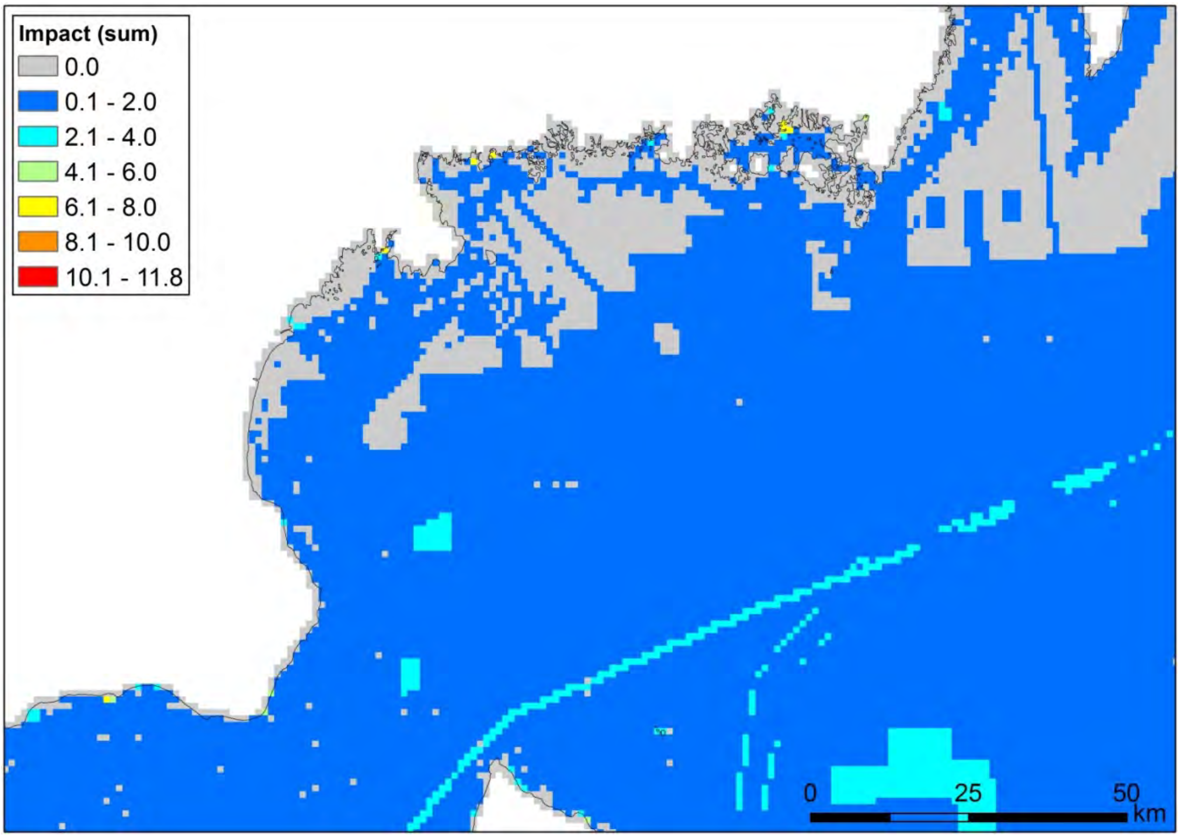
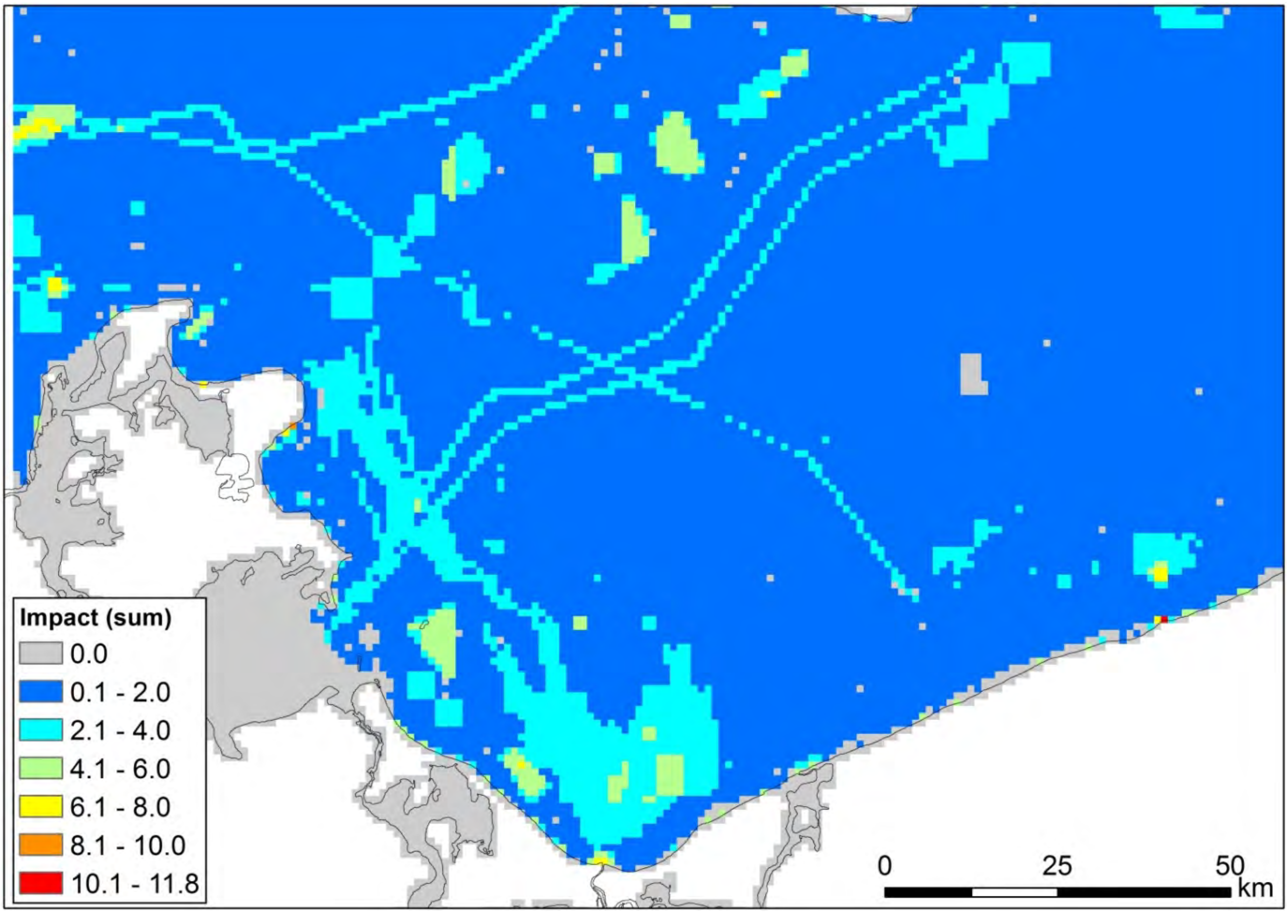


Figure 8. Cumulative impacts on benthic broad-scale habitats in the Pomeranian Bay.



4. Protocol for assessing cumulative impacts

1. Define the assessment area. This is a GIS (Geographical information system) file in vector format of the area where the assessment is applied. Here the HELCOM Convention Area was used.

2. List and define human activities and pressures. All human activities and pressures of relevance for the assessment area were listed and organized to identify which activity is causing or contributing to which pressure (that is, the linkage framework). Here, the data sets were organized in relation to Annex III of the EU Marine Strategy Framework directive (EC 2017a,b, see chapter 3.3).

3. List and define ecosystem components. Habitats, species or functional groups of high ecological importance for the assessment area were listed and defined at a scale broad enough to capture Baltic-wide features. Here, the following were used: 1) benthic habitats based on the EMODnet broad-scale habitats and Natura 2000 habitats, 2) habitat-forming species, 3) pelagic habitats defined as the photic surface layer and the layer beneath, 4) mobile species (mammals, birds and fish species characteristic species for the Baltic Sea, as well as the habitats they use, see chapter 3.4.

4. Define the time scale. Here the data represents the years 2011-2016

5. Collect spatial data sets based on steps 2 and 3. The data must cover the entire assessment area. In some cases direct pressure data is not possible to achieve and pressure data may need to be estimated from data on human activities associated with that pressure (see chapter 3.3). The pressure data

should be quantitative and preferably measured using the same metric. If this is not possible, alternative methods need to be used (see chapter step 7). The ecosystem components can be represented either quantitatively or as presence/absence data.

6. Prepare GIS files on the pressures and ecosystem components. In the case that data sets on human activities are used to represent a pressures, the data files should consider especially how widely a pressure is likely to be distributed from the location of the activity (see chapter 3.3).

7. Aggregate pressure data layers. This step was included in order to reduce the complexity of the assessment and make an assessment possible at large spatial scale (Baltic-wide scale), and in order to have a balances number of input data set representing different pressure types. Pressure data of similar type were aggregated in line with Annex III of EC (2017). The aggregation is straightforward if the pressures are in the same metric. If the metrics are different, then other aggregation approaches are needed (see Chapter 3.3).

8. Define the assessment unit based on the spatial resolution of the input data. Here, an assessment unit of 1 km × 1 km was used. The choice of size depends on the input data. If the input data is coarse relative to the assessment unit size is used, this may over-estimate impacts. If the input data is detailed relative to the assessment unit size used, this may underestimate impacts.

9. Estimate the habitat and species sensitivity. Here, the sensitivity scores were estimated on the basis of and expert survey and literature review (see Chapter 3.5).

10. Calculate the impact index. Cumulative impacts can be estimated by three alternative methods in the EcoImpactMapper software (Stock 2016). Here the ‘sum’ method is used. Alternatively, the BSII can be calculated in the ArcMap Raster Calculator.

11. Present the outcome. The index results are usually presented as maps and in addition, but other graphs can be produced to visualize key results can be produced. In addition to showing the total results, the index can be calculated with respect to separate subsets of pressures or ecosystem components.

12. Validation. The results are compared with other assessment results in the Baltic Sea, such as thematic assessments of biodiversity, eutrophication and contaminants.

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Annex 1. Consideration of spatial and temporal aspects of the data layers of anthropogenic pressures to be used in the Baltic Sea Impact Index.

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent[3]	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Physical loss (permanent effects on the seabed)	Cumulative (summed over the period)	Land claim	Area of polygon or 50 m buffer for points, 30m buffer for lines	Calculate area lost (polygon)	Not relevant	Activities are combined andpotentially overlapping areas are removed. Combined layer is intersected with 1 km grid to calculate % of area lost within a cell.
		Water course modification	50 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Coastal defence and flood protection	50 m buffer for lines, 100 m buffer for points	Calculate buffer to indicate lost area	Not relevant	
		Extraction of sand and gravel	area of polygon	Calculate area lost (polygon)	Not relevant	
		Deposition of dredged material	area of polygon or a 500 m buffer	Calculate area lost (polygon)	Not relevant	
		Dredging (capital and maintenance)	area of polygon or a 25/50 m buffer for <5000 m3 / >5000m3 sites	Calculate area lost (polygon/buffer)	Not relevant	
		Oil platforms	25 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Pipelines	15 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Wind farms	30 m buffer around each turbine	Calculate area lost (polygon)	Not relevant	
		Cables	1.5 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Harbours	polygon with 200 m buffer	Calculate area lost (polygon)	Not relevant	
		Marinas and leisure harbours	point with 200 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Bridges	2 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Bathing sites, beaches	300 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Oil terminals, refineries	point with 200 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Finfish mariculture	150 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Shellfish mariculture	area of polygon	Calculate buffer to indicate lost area	Not relevant	

[3] Note that the spatial extent values in the column D are interim and will be revised according to results from the literature review(BalticBOOST WP3) and expert survey (TAPAS Theme 1).

Physical disturbance or damage to seabed (temporary or reversible effects)	Temporary (averaged between the years)	Shipping density	AIS data calculated directly to 1 km grid cells.	Average of total shipping density in a 1km x 1 km cell 2011-2014, log-transformed, normalized	rescaled with depth: 0-10 m= 100% 10-15 m= 50% 15-20 m= 25% 20-25 m= 10% 25m < =0%	Spatial extents, including spatial attenuation of the pressures, are calculated per specific data sets. Mean pressure intensity per grid cell is assigned to the grid cell. The final grid cell intensity is downweighted (by areal %) if the pressure area is smaller than the grid cell. Activities are weighted according to the method described in the document. All the pressure intensities of specific pressure layers are summed per grid cell.
		Recreational boating and sports	Total fuel consumption of recreational boats modelled directly to 1 km grid cells.	Total fuel consumption of leisure boats modelled in SHEBA project. Fuel usage range in a 1km x 1 km cell in 2014, log-transformed, normalized	rescaled with depth: 0-5m= 100% 5-7 m= 70% 7-10 m= 50% 10-15 m= 10% 15m < =0%	
		Extraction of sand and gravel	400 m buffer suggested	Average amount of extracted material over years, if value missing, 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Dredging	1 km buffer considered, point and polygon data converted directly to 1 km grid cells	Average amount of dredged material over years, if value missing 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Deposit of dredged material	1.5 km buffer considered, point and polygon data converted directly to 2 km grid cells	Average amount of deposited material 2011-2014, if value missing 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Bathing sites, beaches	1 km buffer considered, point data on beaches converted directly to 1 km grid cells.	Amount of bathing sites in a cell, normalized	Not relevant	
		Wind farms (construction)	300 m buffer considered for windfarms under construction, polygon data converted directly to 1 km grid cells.	Location of wind farms under construction	Weighted by the exposure map	
		Cables (construction)	100 m buffer considered for cables under construction, line data converted directly to 1 km grid cells	Location of constructed cables, rescaled intensity to 0.6	Weighted by the exposure map	
		Pipelines	300 m buffer considered	Location of pipelines, rescaled intensity to 0.8	Weighted by the exposure map	

		Demersal fishing intensity	0.05 x 0.05 c-square degree grid (reporting unit for VMS data from ICES)	Average of seabed surface contacting gear fishing intensity (Surface area ratio) in 2011-2013, logtransformed, normalized	Not relevant	
		Water course modification (construction)	No watercourse modification under construction reported	No watercourse modification under construction in 2011-2015	Not relevant	
		Coastal defence and flood protection (construction)	500 m buffer considered, point and line data converted directly to 1 km grid cells	Location of coastal defence and flood protection under construction	Weighted by the exposure map	
		Finfish mariculture	300 m buffer considered, point data converted directly to 1 km grid cells	Average P load 2011-2015, if values missing 25% percentile of the remaining was given, normalized	Weighted by the exposure map	
		Shellfish mariculture	300 m buffer considered, polygon data converted directly to 1 km grid cells	Average production in 2011-2015, if values missing, 25% percentile of the remaining was given, normalized	Weighted by the exposure map	
		Maerl and furcellaria harvesting	No buffer considered, polygon data converted directly to 1 km grid cells	Calculated amount/area of harvested material, normalized	Not relevant	
		Scallop and blue mussel dredging	No buffer considered, polygon data converted directly to 1 km grid cells	Sum of scallop and blue mussel dredged per year, averaged for 2011-2015, normalized	Not relevant	

A. Aggregated pressure	**B. Temporal nature**	**C. Spatial datasets to be combined**	**D. Spatial extent (***	**E. Data used for analysis / data processing**	**F. Depth / exposure**	**G. Aggregation method**
Changes to hydrological conditions (e.g. by constructions impeding water movements)	cumulative	Hydropower dams	a grid cell in the estuary	locations of hydropower dams - those that are operational and produces energy	Not relevant	Spatial extents and potential attenuation gradients are assigned to the specific pressure layers. They are merged (by affected area, km2) to avoid overlapping areas. Intersected with 1 km grid to calculate % of area affected within a cell.
		Water course modification	1 km buffer	Location of water course modifications	Not relevant	
		Wind farms	100 m buffer around each turbine	Location of operational wind farms as polygons	Not relevant	
		Oil platforms	100 m buffer around the platform	Location of oil platforms as points	Not relevant	
Inputs of continuous anthropogenic sounds (into water)	temporary	Ambient underwater noise	BIAS project ambient underwater noise data modelled into 0.5 km x 0.5 km grid	Ambient underwater noise of frequencies of 63, 125 and 2000 Hz exceeding noise levels 95% of the time in full water column during 2014	Not relevant	Average of decibels of 3 different frequencies

Inputs of impulsive anthropogenic sound (into water)	temporary	Impulsive noise events	Data converted directly to 1km grid cells	Data from HELCOM-OSPAR Database for impulsive noise and national data call (polygons, points, lines) with noise values categorized from very low, low, medium, high and very high	Not relevant	Average of events based on noise value codes
Inputs of other form of energy (electromagnetic waves)	temporary	Cables	No buffer considered, line data converted directly to 1 km grid cells	Location of cables	Not relevant	Not relevant
Input of heat (e.g. by outfalls from power stations) into water	temporary	Discharge of warm water from nuclear power plants	Gradual buffer around outlet	Average input of warm water (Celcius) from the nuclear power plant outlets	Not relevant	Sum of the input of warm water.
		Fossil fuel energy production (only location available)	Gradual buffer around outlet	Average input of warm water (Celcius) from the nuclear power plant outlets	Not relevant	

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent (*	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Input of hazardous substances	temporary	CHASE Assessment tool concentration component: results per assessment unit	HELCOM assessment units	Contamination Sum of the CHASE Assessment tool concentration component	Not relevant	Not relevant
Introduction of radionuclides	temporary	Discharges of radioactive substances	Gradual buffer around outlet to 10 km distance	Annual averages of CO60, CS137 and SR90 from the period 2011-2015 per nuclear power plant. Aggregation to be agreed intersessionally between HELCOM Mors Expert group and the Secretariat.	Not relevant	Not relevant
Oil slicks and spills	temporary	Oil slicks and spills from ships and oil platforms	Buffer area depending on reported spill area	If oil spill volume was missing (67/560), median of the rest was given. If area of spill was missing (103/560), mean of the existing was given. If the spill was < 1km2, the value of spill volume was given directly to 1km2 grid cell. If the spill area > 1km2, the estimated volume of the spill was divided by the spill area to get the estimated amount of oil / km2. This value was given to the entire spill area.	Not relevant	sum of spill volume

		Polluting ship accidents	point, converted directly to 1 x 1 km grid	9/24 accidents with oil spills were missing spilled oil volume, thus a mean of reported volumes was given to accidents with missing oil volume. Spill volume in m3 was converted to grid	Not relevant	
Inputs of litter[4]	temporary	Beach litter	points converted directly to 1 x 1 km grid	Beach litter indicator to be used as proxy for pressure. Presence/absence of beach litter	Not relevant	Sum of presence of beach litter and litter on sea floor
		Bottom trawled litter from seafloor	information converted directly to 1 x 1 km grid	DATRAS database on trawl surveys (ICES)	Not relevant	
Inputs of nutrients	temporary	Interpolated nitrogen and phosphorus concentrations (	Mean value per grid cell	N and P concentrations	Not relevant	Not relevant (separate data layers)
Inputs of organic matter [4]	temporary	Riverine input of organic matter	plume based on satellite images	concentration based on different proxies (e.g. BOD, COD values)	Weighted by the exposure map	Not relevant

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent (*	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Disturbance of species due to human presence	temporary	Recreational boating and sports	Total fuel consumption of recreational boats modelled directly to 1 km grid cells.	Total fuel consumption of recreational boats presented as presence / absence	rescaled with depth: 0-10m= 100% 10-15 m= 70% 15-20 m= 50% 20-30 m= 20% 30-40 m = 10% 45m < =0%	Specific pressure layers first modified by spatial extents and depth influence. Each of them is considered as of equal importance (same weight). Calculate the sum of the pressure in a cell.
		Bathing sites, beaches	point data converted directly to 1 km grid cells	Location of beaches presented as presence / absence	Not relevant	
		Urban land use	polygon data converted directly to 1 km grid cells	presence / absence	Not relevant	
Extraction of, or mortality/injury to fish	temporary	Extraction of target fish species (cod, herring, sprat, flounder) in commercial fishery	Reported per ICES Rectangles, covers the whole Baltic Sea	Extraction of fish species (landings) per ICES rectangle, average of 2011-2014. Landings calculated per km2.	Not relevant	Log transformed. For cod, recreational fisheries catches were added (see below).
		Extraction of fish species by recreational fishery	Reported per country for eel, cod and salmon (tonnes).	Extraction of fish species by recreational fishing, average of 2011-2014. For cod, recreational landings (tonnes/km2) were added to commercial catches.	Not relevant	Tonnes/km2 values for cod, summed with tonnes/km2 values from commercial catches. Log transformed.
Extraction of, or mortality/injury to seabirds (e.g. hunting, predator control)	temporary	Game hunting of seabirds	Varying reporting units, from counties to HELCOM subdivisions	Species summed together, average of killed seabirds of years 2011-2015 per reporting unit, numbers of killed birds / km2 calculated and generalized for the whole reporting unit, normalized	Not relevant	normalized values summed together

[4] Was not used due to the lack of spatial data.

		Predator control of seabirds	Varying reporting units, from counties to HELCOM subdivisions	Total number of killed cormorants per year averaged for 2011-2015, numbers of killed birds / km2 calculated and generalized for the whole reporting unit, normalized	Not relevant	
Extraction of, or mortality/injury to mammals	temporary	Hunting of seals	Varying reporting units, from counties to HELCOM subdivisions	Total number of killed seals (per species) averaged for 2011-2014, numbers of killed seals/ km2 calculated, and generalized for the whole reporting unit, normalized	Not relevant	Not relevant (as the species are presented separately in the ecosystem components)
Introduction of non-indigenous species and translocations	cumulative	Spread of non-indigenous species	Reported per coastal areas	Number of NIS per HELCOM sub-basins and coastal areas, generalized for the whole reporting unit.	Not relevant	Not relevant

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent	E. Data used for analysis / data processing	F. Depth / exposure	G. Combination method
Change in climatic conditions [5]		Long term change in sea surface salinity (PSU), and sea surface temperature (degrees Celsius)	Point data covering the Baltic Sea	Long-term monitoring data on sea surface salinity and temperature from ICES database. Coastal monitoring sites (<2km to land) excluded. Mean of July-August values at 10m depth (surface) calculated for 1960-2010 (presenting long-term) and for 2011-2015 (assessment period) per HELCOM sub-basin. Change in temperature and salinity calclulated. Temp. increase is expected with climate change, thus subbasins showing decrease are given 0 values. Data normalized. Salinity decrease is expected with climate change, thus subbasins showing increase, are given 0 values. Data normalized.	Not relevant	Not summed (as change in temperature is likely to have different effects on the ecosystem, than change in salinity)

[5] Was not used due to the lack of spatial data.

Acidification		Long term change in pH	Point data covering the Baltic Sea, some sub-basins missing data on pH (Great Belt, the Sound, Kiel Bay, Arkona Basin)	Long-term monitoring data on pH from ICES database. Coastal monitoring sites (<2km to land) excluded. Mean of July-August values at 10m depth (surface) calculated for 1960-2010 (presenting long-term) and for 2011-2015 (assessment period) per HELCOM sub-basin.. Change in pH calclulated. Normalized.	Not relevant	Not relevant

Annex 2. Description of the ecosystem component layers

This annex gives more detailed descriptions of the ecosystem component data layers.

1. Productive surface waters

- The surface waters can be considered as the photic layer, but in reality the layer is made on the basis of springtime Chl-a concentration which is used as a proxy for the productive surface waters. Areas with high springtime phytoplankton production are given higher importance in this layer as these are considered as important areas for the Baltic food web. Springtime (weeks 12-22) Chl-a concentration of the surface waters derived from satellite data (MERIS). As there is no MERIS data available for years 2012-1016, older data will be used (mean of 2003-2011). The data for eastern Baltic is provided by the Finnish Environment Institute. For the western Baltic, coarser resolution MERIS data from JRC-database will be used. Finnish Environment Institute will update the finer resolution data in 2017 to cover the whole Baltic Sea. The updated data can be used in the final version of the BSII.

2. Oxygenated deep waters

- The deep water habitats are defined as those areas which do not suffer from hypoxia. Areas of severe hypoxia (<2 mg/L) are omitted from this habitat layer. Moreover, near-bottom oxygen concentrations (i.e. > 2 mg/L) are used to weight the layer, i.e. the higher the O2 concentration, the more important the area is. Data requests have been made to Swedish Meteorological and Hydrological Institute (SMHI). They are currently in the process of updating the data and the data will be delivered by the end of 2016, for years 2011-2016.

Broad-scale seabed habitats

Broad-scale habitats are level 3 habitats according to HELCOM underwater biotope and habitat classification system (HUB) (or level 2 habitats according to EUNIS classification system). The broad-scale habitats are used as proxies for the biological communities that are found in these environments**.** The spatial data on broad-scale seabed habitats will be obtained directly from the EUSeaMap II -project. A new updated version is ready and is released in October 2016.

3. Infralittoral hard bottom

- *Cladophora spp., Ceramium spp., Laminaria sp., Fucus sp., Furcellaria lumbricalis, Polysiphonia fucoides, Aegagrophila linnaei, Fontinalis sp.* Ascidiaceae, *Electra crustulenta, Flustra foliacea,* Balanidae, *Mytilus* spp.,*Modiolus modiolus*

4. Infralittoral sand

- *Phragmites australis, Zostera marina, Potamogeton perfoliatus, Stuckenia pectinata, Tolypella nidifica, Chara aspera, Hediste diversicolor, Bathyporeia pilosa, Arenicola marina, Macoma balthica, Mya arenaria.*

5. Infralittoral mud

- *Phragmites australis, Stuckenia pectinata, Potamogeton perfoliatus, Najas marina, Chara tomentosa, Hediste diversicolor, Gammarus spp.*

6. Circalittoral hard bottom

- *Mytilus* spp., *Cordylophora caspia,* Hydrozoa, *Amphibalanus improvisus,* Bryozoa, Porifera, Hydrozoa

7. Circalittoral sand

- *Mya arenaria, Macoma baltica, Arctica islandica, Pygospio elegans, Marenzelleria spp., Hediste diversicolor, Monoporeia affinis,* Chironomidae

8. Circalittoral mud

- *Macoma balthica, Saduria entomon, Marenzelleria* spp, *Monoporeia affinis*

Habitat forming species

The maps of habitat forming species are based on data submission by countries, as a result of data call on species and biotopes.

The following habitats forming species are considered:

9. Furcellaria lumbricalis
10. Zostera marina
11. Charophytes
12. Mytilus edulis
13. Fucus sp.

The data was mainly submitted as point data on species observations. Only Finland and Estonia submitted results of predictive models on species presence, Finland submitted also point data. The Estonian predictive model (200m resolution) was converted to presence/absence using minimized difference threshold (MDT) criteria. All data (species point observations and the raster presenting predicted presence of species for Estonian waters) were generalized to 5km x 5km grid cells.

Natura 2000 habitats

Natura 2000 habitats are habitats listed in the Annex 1 of the Habitats Directive, and named as habitat types, whose conservation requires the designation of special areas of conservation (SACs). Full descriptions of the habitats can be found at the following link: http://ec.europa.eu/environment/nature/-legislation/habitatsdirective/docs/Int_Manual_EU28.pdf.

The maps of Natura 2000 habitats are based data submission by countries, as a result of data call on species and biotopes. Most of the submitted data (polygons) on Natura 2000 habitats are based on modelling, GIS analysis and/or aerial photos. Data coverage, accuracy and the methods in obtaining the data vary.

14. Sandbanks which are slightly covered by sea water at all time (1110)

- Sandbanks are areas elevated from their surroundings that consist mainly of sand, but where cobbles and boulders can occur. Occur usually in < 20m depth. Characteristic plant species include *Zostera* sp., *Potamogeton* spp., *Ruppia* spp., *Tolypella nidifica*, *Zannichellia* spp., charophytes.

15. Estuaries (1130)

- Estuaries are coastal inlets that are strongly influenced by freshwaterCharacteristic species include e.g. *Carex* spp., *Myriophyllum* spp., *Phragmites australis*, *Potamogeton* spp., *Scirpus* spp.).

16. Mudflats and sandflats not covered by seawater at low tide (1140)

- This habitat contains sands and muds not covered by sea water at low tide, often devoid of vascular plants, usually coated by blue algae and diatoms. These habitats host diverse intertidal communities of invertebrates. They are of particular importance as feeding grounds for wildfowl and waders.

17. Coastal lagoons (1150)

- Lagoons are expanses of shallow coastal waters, entirely or partially separated from the sea by sandbanks, shingle, or rocks. Salinity may vary from brackish water to hypersaline depending on rainfall, evaporation and addition of fresh seawater from storms, temporary flooding, or tidal exchange. Characteristic species include e.g. *Callitriche* spp*., Chara* sp., *Eleocharis parvula, Lamprothamnion papulosum, Ranunculus baudotii, Ruppia maritima, Tolypella nidifica.* In flads and gloes *also Lemna trisulca, Najas marina, Phragmites australis, Potamogeton* spp.*, Stratiotes aloides, Typha* spp*.*

18. Large shallow inlets and bays (1160)

- These habitats are large, shallow indentations of the coast, sheltered from wave action and where, in contrast to estuaries, the influence of freshwater is generally limited. Characteristic species include e.g. *Zostera* spp., *Ruppia maritima*, *Potamogeton* spp.

19. Reefs (1170)

- Reefs are hard compact substrata on solid and soft bottoms, which arise from the seafloor in the sublittoral and littoral zone. They may be either biogenic or geogenic. Characteristic species include red, brown and green algae, and bivalves (e.g. *Modiolus modiolus*, *Mytilus* sp., *Dreissena polymorpha*).

20. Submarine structures made by leaking gas (1180)

- These habitats are also known as "bubbling reefs". These formations support a zonation of diverse benthic communities consisting of algae and/or invertebrate specialists of hard marine substrates different to that of the surrounding habitat.

21. Baltic Esker Islands (UW parts, 1610)

- These habitats are glaciofluvial islands consisting mainly of relatively well sorted sand, gravel or less commonly of till. Also their underwater parts are included in the habitat. Characteristic species include e.g. *Potamogeton sp., Myriopyllum sibiricum, Ceramium tenuicorne, Chorda filum, Chara aspera, Cladophora glomerata, Fucus vesiculosus, Pilayella littoralis*

22. Boreal Baltic islets and small islands (UW parts, 1620)

- Groups of skerries, islets or single small islands, mainly in the outer archipelago or offshore areas. They are important nesting sites for birds and resting sites for seals. The surrounding sublittoral vegetation is also included. The species composition is often very similar to reefs (1170).

Commercial fish species

23. Cod abundance

- Baltic International Trawl Survey (BITS) data from ICES DATRAS database was used from 2011-2014 to create a map of cod abundance (quarter 1 data, CPUE values per ICES subdivision). Cod ≥ 30cm was included. As the BITS data do not cover the whole cod distribution area, landings data (from DCF) was used to complement the data. If the total catch within the ICES statistical rectangle (all 4 years summed) was >0.5 tonnes and the number of years when cod has been caught within the statistical rectangle was >1, the area was considered as cod distribution area. A value corresponding low CPUE values (BITS data) was given to these areas. Currently the data from Kattegat (subdivision 21) is not standardized with the rest of the area.

24. Cod spawning area

- In comparison to previously reported spawning grounds (e.g. Bagge et al. 1994), Gotland and Gdansk basins have ceased to significantly contribute to the reproduction of the Eastern Baltic cod due to oxygen deficiency and sedimentation related mortality (Hinrichsen et al. 2016). Thus, the current cod spawning map represents spawning areas for both eastern and western Baltic cod. The delineation of the spawning area is according to Hüssy 2011.

25. Herring abundance

- The map of herring abundance is mainly based on Baltic International Acoustic Surveys (BIAS) (ICES WGBIFS reports 2012-2016). The data is reported as millions of herring / ICES statistical rectangle. As the surveys don't cover the whole Baltic Sea, herring landings data were used to complement the data. The landings data indicated that herring is found in the whole Baltic Sea, thus a constant value of 10 (millions of herring/per ICES rectangle) was given to all areas outside BIAS data, corresponding to low abundance within area covered by BIAS data.

26. Sprat abundance

- The map of sprat abundance map is mainly based on Baltic International acoustic surveys (BIAS) (ICES WGBIFS reports 2012-2016). The data is reported as millions of herring / ICES statistical rectangle. Also sprat landings data were used to evaluate sprat distribution area. According to the landings data, the BIAS surveys cover almost the whole area where sprat is commonly encountered. In the few areas with significant sprat landings but outside BIAS area, a value of 1 (millions of sprat/ICES rectangle) was given. (Significant landings: the total landings within the statistical rectangle (all years summed) >1 tonne, the number of years when sprat caught within the statistical rectangle >1).

Coastal fish

27. Distribution of demersal spawning flounder

- Flounder in the Baltic Sea can be divided to two different ecotypes, to demersal spawning flounder and to pelagic spawning flounder (Florin & Höglund 2008). The pelagic spawning flounder is distributed in the southern and the deeper eastern part of the Baltic Sea and the demersal spawners in the northern area, excluding Bothnian Bay and Eastern Gulf of Finland (Florin & Höglund 2008, ICES 2014). The two ecotypes co-occur in ICES subdivisions 25, 26 and 28 (Florin et al. 2015). The distribution area of demersal spawning flounder is delineated by selecting area with depth < 50m within ICES subdivisions 25-32 (Florin & Höglund 2008, Florin et al. 2015, ICES 2014). To exclude areas with < 5 psu salinity (ICES 2014), Bothnian Bay, Quark, and the Russian part of Gulf of Finland were excluded from the map, according to HELCOM sub-basin division.

28. Abundance of pelagic spawning flounder

- The abundance (CPUE) map of pelagic spawning flounder is based on ICES Baltic International Trawl Surveys (BITS, ICES 2014a). However, in the ICES subdivisions 25, 26 and 28 also demersal spawners can be included in the CPUE values (Florin et al. 2015).

29. Recruitment areas of perch

- The occurrence of suitable nursery habitats is crucial for maintaining fish populations. Due to lack of coherent data on perch spawning and nursery areas across the Baltic Sea countries, it was decided to use environmental variables in delineating potential reproduction areas for perch. For perch, species distribution modelling studies (Snickars et al. 2010, Bergström et al. 2013, Sundblad et al. 2013) have shown the importance of suitable environmental conditions for reproduction. The distribution area or perch reproduction is delineated by selecting areas where depth < 4 m, logged exposure < 4 (according to model described in Isæus 2004), and salinity < 10 PSU. The threshold values have been obtained from literature (Snickars et al. 2010, Bergström et al. 2013, Skovrind et al. 2013, Sundblad et al. 2013).

30. Recruitment areas of pikeperch

- Due to lack of coherent data on pikeperch spawning and nursery areas across the Baltic Sea countries, it was decided to use environmental variables in delineating potential reproduction areas for pikeperch. The pikeperch recruitment area is delineated by selecting areas where depth < 5 m, logged exposure < 4 (according to model described in Isæus 2004), salinity < 7 PSU, Secchi depth < 2 m and distance to deep water (10 m depth) > 4km. The threshold values have been obtained from literature (Veneranta et al. 2011, Bergström et al. 2013, Sundblad et al. 2013, Kallasvuo et al. 2016). Temperature, although important for pikeperch, was left out due to high variation in the timing of suitable spawning temperatures across the Baltic Sea.

31. Recruitment areas of roach

- The map representing recruitment areas of roach is still under development. A plan is to use similar approach as for perch and pikeperch recruitment areas, but due to difficulties in finding suitable thresholds for different environmental variables, it may not be achievable.

Important Bird Areas

The spatial data on important bird areas (list items 32-34) are based on a data call, where an update to IBA and SPA data has been requested from the countries. Also a separation of these areas into wintering and breeding areas was hoped for, if possible. At this point 4 countries have submitted the data, and 3 out of 4 were able to separate between breeding and wintering areas.

32. Wintering seabirds

33. Breeding seabird colonies

34. Migration routes for birds

- Not enough data at this stage to produce a Baltic-wide map.

Marine mammals

SEAL EG 10 proposed to use the marine mammal maps from the 2013 HELCOM Red List assessment for the impact index and suggested to review and, if needed, to modify the maps based on expert opinion. The SEAL EG will be consulted intersessionally in the finalization of the maps for use in BSII.

35. Grey seal abundance
36. Grey seal haul-outs
37. Harbour seal abundance
38. Harbour seal haul-outs
39. Ringed seal distribution
40. Distribution / density of harbour porpoise

Annex 3. The expert survey. In order to use the survey, users should enable the macros of the file.

HELCOM_TAPAS_survey.xlsm

Annex 4. Summarized results of the expert survey to estimate tolerance, recoverability, sensitivity, impact distance and impact type of 19 pressures to 40 ecosystem components.

TAPAS
Expert_survey result

Annex 5. Final sensitivity scores of the 40 ecosystem components to 19 pressures.

The sensitivity scores from the expert survey were processed and the final scores

Sensitivity scores: average	1. Physical loss (permanent effects on the seabed)	2. Physical Disturbance or damage to seabed (temporary or reversible effects)	3. Changes to hydrological conditions (e.g. by constructions impeding water movements)	4. Inputs of continuous anthropogenic sounds (into water)	5. Inputs of impulse anthropogenic sound (into water)	6. Inputs of other form of energy (electromagnetic and seismic waves)	7. Input of heat (e.g. by outfalls from power stations) into water	8. Inputs of hazardous substances	9. Inputs of nutrients	10. Introduction of radionuclides	11. Oil slicks and spills	12. Inputs of litter	13. Inputs of organic matter	14. Disturbance of species due to human presence	15. Extraction of, or mortality/injury to fish	16. Extraction of, or mortality/injury to mammals and seabirds (e.g. hunting, predator control)	17. Introduction of non-indigenous species and translocations	18. Changes in climatic conditions	19. Acidification
1. Productive surface waters	0.4	1.0	0.6	0.6	0.6	0.4	1.0	**1.5**	1.5	0.0	1.4	0.4	1.1	0.8	1.0	0.5	1.0	1.4	1.2
2. Oxygenated deep waters	0.9	0.7	1.3	0.5	0.6	0.5	0.6	**1.5**	1.8	0.0	1.0	0.3	0.9	0.2	0.7	0.3	0.7	1.7	0.8
3. Infralittoral hard bottom	**2.0**	**1.6**	1.2	0.2	0.2	0.6	1.3	**1.5**	1.3	0.4	1.7	0.4	**1.7**	0.3	0.6	0.7	1.1	1.4	1.1
4. Infralittoral sand	**2.0**	**1.5**	0.9	0.3	0.3	0.5	1.0	**1.5**	1.3	0.2	1.4	0.3	**1.7**	0.3	0.3	0.7	0.9	0.7	0.9
5. Infralittoral mud	**2.0**	**1.4**	1.1	0.3	0.3	0.6	1.0	**1.5**	1.3	0.4	1.4	0.4	**1.9**	0.4	0.3	0.7	0.9	0.8	0.9
6. Circalittoral hard bottom	**2.0**	**1.6**	1.4	0.3	0.3	0.6	1.2	**1.5**	1.3	0.5	1.3	0.4	**1.9**	0.4	0.8	1.0	1.2	1.5	1.4
7. Circalittoral sand	**2.0**	**1.4**	1.1	0.2	0.3	0.5	0.7	**1.5**	1.2	0.2	0.9	0.3	**1.8**	0.3	0.3	0.7	1.0	0.7	0.9
8. Circalittoral mud	**2.0**	**1.3**	1.3	0.3	0.3	0.8	0.9	**1.5**	1.2	0.5	1.1	0.5	**1.7**	0.4	0.6	0.5	0.9	0.7	1.0
9. Furcellaria lumbricalis	**2.0**	1.7	1.7	0.2	0.3	0.6	1.5	**1.5**	1.5	0.5	1.5	0.3	**1.6**	0.6	0.7	0.7	0.8	1.1	0.7
10. Zostera marina	**2.0**	1.9	1.7	0.2	0.1	0.5	1.6	**1.5**	1.9	0.6	1.6	0.4	**2.0**	1.2	0.9	0.8	0.7	1.0	0.6
11. Charophytes	**2.0**	1.9	1.4	0.0	0.0	0.6	0.9	**1.5**	1.7	0.4	1.5	0.3	**1.8**	0.7	0.8	0.7	0.9	0.7	0.6
12. Mytilus edulis	**2.0**	1.6	1.6	0.2	0.1	0.5	1.0	**1.5**	0.9	0.5	1.6	0.5	**1.5**	0.4	0.4	0.2	0.9	1.1	0.9
13. Fucus sp.	**2.0**	1.7	1.3	0.3	0.3	0.5	1.5	**1.5**	1.3	0.5	1.4	0.4	**1.7**	0.6	0.5	0.3	0.8	1.1	0.5

14. Sandbanks which are slightly covered by sea water at all time (1110)	1.9	1.6	1.3	0.2	0.2	0.5	0.9	**1.5**	1.5	0.4	1.5	0.6	**1.9**	1.1	0.9	1.0	0.9	0.8	0.6
15. Estuaries (1130)	1.8	1.6	1.5	0.8	0.9	0.8	0.9	**1.5**	1.4	0.7	1.6	0.8	**1.3**	1.0	1.1	0.8	1.3	0.9	1.0
16. Mudflats and sandflats not covered by seawater at low tide (1140)	1.9	1.7	1.8	0.2	0.2	0.5	1.7	**1.5**	1.5	0.3	1.8	0.8	**1.9**	1.0	0.9	0.8	0.9	0.8	1.5
17. Coastal lagoons (1150)	1.9	1.7	1.6	0.7	0.8	0.6	1.3	**1.5**	1.5	0.2	1.7	0.6	**1.7**	1.0	1.1	0.6	1.4	1.3	1.0
18. Large shallow inlets and bays (1160)	1.8	1.6	1.3	0.8	0.9	0.8	1.2	**1.5**	1.3	0.2	1.6	0.6	**1.5**	0.9	1.1	0.7	1.3	0.9	1.0
19. Reefs (1170)	2.0	1.6	1.4	0.3	0.3	0.6	1.0	**1.5**	1.3	0.6	1.9	0.7	**1.7**	0.8	0.9	1.1	1.2	1.2	0.9
20. Submarine structures made by leaking gas (1180)	1.7	1.2	1.3	1.0	1.0	1.0	1.0	**1.5**	1.6	0.5	1.8	0.7	**1.6**	1.0	0.8	1.5	1.4	1.0	2.0
21. Baltic Esker Islands (UW parts, 1610)	1.8	1.5	1.3	0.5	0.5	0.5	1.0	**1.5**	1.3	0.1	1.6	0.4	**1.6**	0.7	0.8	0.5	1.3	1.0	2.0
22. Boreal Baltic islets and small islands (UW parts, 1620)	1.8	1.5	1.1	0.5	0.5	0.5	1.0	**1.5**	1.2	0.1	1.6	0.5	**1.6**	0.7	0.8	0.5	1.3	1.3	2.0
23. Cod abundance	1.0	0.7	0.4	0.2	0.9	0.5	0.7	**1.6**	1.5	0.6	0.5	0.2	1.1	0.9	1.6	0.7	0.6	1.1	0.3
24. Cod spawning area	0.7	0.8	0.9	0.6	1.0	0.5	0.6	**1.6**	1.7	0.5	1.0	0.1	0.8	0.6	1.3	0.2	0.4	1.6	0.8
25. Herring abundance	0.9	0.7	0.7	0.6	1.1	0.5	0.6	**1.6**	0.7	0.3	0.9	0.1	0.2	0.4	1.2	0.2	0.6	1.0	0.6
26. Sprat abundance	0.5	0.5	0.7	0.6	1.1	0.5	0.6	**1.6**	0.6	0.3	0.9	0.1	0.2	0.4	1.2	0.2	0.6	1.1	0.6
27. Distribution of demersal spawning flounder	1.7	1.3	0.8	0.2	0.7	0.6	0.7	**1.6**	1.6	0.5	1.3	0.4	0.8	1.0	1.8	0.3	0.9	1.4	1.0
28. Abundance of pelagic spawning flounder	1.0	0.8	0.9	0.3	0.7	0.6	0.8	**1.6**	1.3	0.4	1.1	0.3	0.7	0.9	1.8	0.0	0.8	0.8	1.0
29. Recruitment areas of perch	**1.8**	**1.6**	1.2	0.4	0.9	0.7	0.4	**1.6**	1.4	0.4	1.6	0.4	1.0	1.3	1.6	0.0	1.0	0.5	1.3
30. Recruitment areas of pikeperch	**1.8**	**1.4**	1.2	0.6	1.1	0.7	0.3	**1.6**	0.7	0.5	1.7	0.3	0.9	1.0	2.0	0.5	0.9	0.3	1.0
31. Recruitment areas of roach	**1.8**	**1.5**	1.2	0.6	1.0	0.4	0.3	**1.6**	0.5	0.5	1.7	0.4	0.9	0.8	1.6	0.5	0.9	0.3	1.0
32. Wintering seabirds	0.9	0.8	0.5	0.8	0.9	0.6	0.4	**1.8**	0.2	0.7	2.0	1.1	0.4	1.3	1.1	1.7	0.6	1.1	0.8
33. Breeding seabird colonies	0.9	0.9	0.4	0.6	0.8	0.3	0.3	**1.8**	0.3	0.2	2.0	0.9	0.4	1.8	1.0	1.6	0.8	1.1	0.8
34. Migration routes for birds	0.8	0.5	0.4	0.7	0.8	0.0	0.6	**1.8**	0.2	0.0	1.9	1.0	0.3	1.4	0.7	1.8	0.3	1.0	0.7

35. Grey seal abundance	0.6	0.7	0.7	1.4	1.6	0.6	0.3	**2.0**	0.3	1.0	1.3	0.9	0.5	1.0	1.2	1.6	0.8	0.9	1.3
36. Grey seal haulouts	0.8	0.9	0.6	1.5	1.5	0.3	0.2	**2.0**	0.3	0.3	1.4	0.9	0.4	1.4	1.0	2.0	0.5	0.9	1.0
37. Harbour seal abundance	0.6	0.7	0.7	1.5	1.6	0.6	0.3	**2.0**	0.3	1.0	1.6	0.9	0.5	1.3	1.2	1.9	0.8	0.8	1.3
38. Harbour seal haulouts	0.8	0.9	0.6	1.5	1.5	0.3	0.2	**2.0**	0.3	0.3	1.6	0.9	0.4	1.6	1.0	2.0	0.5	0.9	1.0
39. Ringed seal distribution	0.5	0.6	0.6	1.5	1.6	0.4	0.6	**2.0**	0.5	1.2	1.4	1.2	0.5	1.2	1.5	1.6	1.1	1.7	1.6
40. Distribution / density of harbour porpoise	1.2	1.3	0.4	1.7	1.9	0.3	0.5	**2.0**	0.2	1.0	1.6	1.0	0.5	1.2	1.5	2.0	0.4	0.9	1.1

Annex 6. Linkage framework

TAPAS linkage framework.xlsx