STATE OF THE BALTIC SEA
- HOLISTIC ASSESSMENT -
First version 2017

# THE ASSESSMENT OF CUMULATIVE IMPACTS USING THE BSPI AND BSII

TO BE UPDATED IN 2018

## -Supplementary Report to the First Version of the 'State of the Baltic Sea' Report 2017

HELCOM – BALTIC MARINE ENVIRONMENT PROTECTION COMMISSION

The assessment of cumulative impacts using the Baltic Sea Pressure Index and the Baltic Sea Impact Index - supplementary report to the first version of the HELCOM 'State of the Baltic Sea' report 2017

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# Summary

Human activities in the Baltic Sea and its catchment area create a variety of pressures on the Baltic Sea environment. Cumulative impacts on species and habitats are caused by multiple pressures taken together. If each of the pressures is considered individually, they may appear to be at sustainable levels. However, when summed together, their total impact may be considerable if they take place in the same area, in particular when acting on sensitive habitats.

This report gives the method description and more detailed results of the assessment of cumulative pressures and impacts, which was carried out as part of the second HELCOM holistic assessment of the ecosystem health of the Baltic Sea (HELCOM 2017a). The results are presented as the Baltic Sea Pressure Index, which shows areas where the greatest pressure from human activities likely occurs, and the Baltic Sea Impact Index, which shows where the impact from cumulative pressures is likely the highest.

The key results from the assessment are also presented in the 'State of the Baltic Sea' summary report (HELCOM 2017a), which gives the results from the second HELCOM holistic assessment. This supplementary report additionally gives a more detailed description of the underlying spatial data sets and the sensitivity scores that were applied in the assessment.

The results show that human activities take place almost everywhere in the Baltic Sea but are mostly concentrated near the coast and close to urban areas. The southwestern Baltic Sea and many coastal areas potentially experience higher cumulative impacts than the northern areas and many open sea areas. However, in areas with poor data coverage the cumulative impacts may currently be underestimated.

The pressures potentially responsible for causing most impacts were inputs of nutrients, contamination, continuous sound and non-indigenous species as well as extraction of fish. These are also the pressures which are the most widely distributed in the Baltic Sea. Other pressures were associated with high potential impact on the species, but had lesser influence to the overall regional scale as they were not as widely distributed.

The assessment is based on spatial information that is regional, so that the results are comparable across areas. Hence, the results give a broad overview, whereas the level of accuracy in detailed results needs to be evaluated on a case by case basis. The input data are foreseen to be further improved before the updated version of this report, due in June 2018, in cases where new information becomes available.

# Chapter 1. Background

The Baltic Sea Pressure Index identifies areas of the Baltic Sea where the cumulative amount of human induced pressures is likely the highest. The Baltic Sea Impact Index estimates the probable cumulative burden on the marine environment based on species' sensitivity at a regional scale.

This report gives the method description and more detailed results of the assessment of cumulative pressures and impacts which was carried out as part of second HELCOM holistic assessment of ecosystem health in the Baltic Sea. The assessment represents the situation during 2011-2015 and was based on Baltic-wide data sets on the spatial distribution of human activities, pressures and ecosystem components.

The report presents the spatial data sets used in the assessment, as well as the sensitivity scores that were used for assessing potential impacts on ecosystem components in the Baltic Sea Impact Index. The key results are also presented in the summary report 'State of the Baltic Sea' (summary report: HELCOM 2017a). The input data are foreseen to be further improved before the updated version of this report (due in June 2018), in cases where new information becomes available.

# Chapter 2. Assessment overview

Pressures from human activities can be broadly categorised into inputs of substances (for example nutrients, litter or contaminants), inputs of energy (underwater sound), biological pressures (introduction of new species, disturbance of species and extraction of species, for example), and physical pressures (disturbance to the seabed, loss of seabed or changes to hydrological conditions). The pressures affect both the biotic and abiotic parts of the marine environment, but in the end they cause impacts to species in different parts of the food web.

The spatial distribution of pressures and impacts in the Baltic Sea was evaluated using two methods: the Baltic Sea Pressure Index (BSPI) and the Baltic Sea Impact Index (BSII). The Baltic Sea Pressure Index evaluates the distribution of pressures and assesses where their current cumulative distribution is highest.

The basis for the assessment was spatial information on the distribution of 54 human activities and pressures in the Baltic Sea during 2011–2015. The data represents a wide range of human activities and potential pressures of relevance to the Baltic Sea, and were compiled into 19 pressure layers for the assessment (See Chapter 3.3). It should be noted, however, that these pressures layers depict the distribution of potential pressures in the Baltic Sea, and that the actual intensity of the pressures in relation to impacts they may cause on the environment is not included.

The Baltic Sea Impact Index estimates the cumulative impacts in the Baltic Sea, by additionally using information on which species and habitats are likely to be present in an area.

In all, 42 data layers representing the distribution of species and habitats within the years 2011–2015 were, as far as available, included (see Chapter 3.3.). These data layers show ecosystem components in their current distribution, and do not include information on where species would occur if there were no pressures due to human activities. For example, the distribution of cod spawning areas is shown based on information on currently functional spawning areas, which have a clearly more limited distribution compared to the past (Köster *et al*. 2017). Hence, the assessment focusses on identifying current potential impacts, given the existing status of species and habitats in the Baltic Sea (see the summary report: HELCOM 2017a).

Cumulative impacts were estimated by combining the information on species and habitats with the information on the distribution of pressures, using estimates of the sensitivity of species and habitats to the different pressures.

The sensitivity was estimated at a three-level scale by sensitivity scores. The scores were obtained from a survey answered by over eighty selected experts in the Baltic Sea region, representing marine research and management authorities in seven Baltic Sea countries. The results were evaluated for compatibility with a literature review study on physical loss and disturbance of benthic habitats, and assessed in relation to a self-evaluation of the experts on their confidence in their replies (see Chapter 3.5). Hence, the BSII evaluates areas where human induced pressures potentially have relatively high or low cumulative impacts on the marine environment. In reality these impacts are often synergistic, so that the total effects of the pressures may be larger than their sum, and there may be ecosystem feedbacks (See Box 6.1 in summary report: HELCOM 2017a). The current version of the BSII does not take these more complex linkages into account.

The results of the BSPI and BSII are an estimation of potential pressures and impacts, created with best available data, but gaps may occur in the underlying datasets. Thus, areas with low impact may imply data gaps and different areas cannot be directly compared at this time. The underlying datasets and metadata can be viewed and downloaded from the HELCOM map and data service.

# Chapter 3. Method for the assessment of cumulative impacts

The Baltic Sea Impact Index (BSII) was first applied in the Initial HELCOM Holistic assessment (HELCOM 2010a), building on concepts described by Halpern *et al*. (2008). The methods that were applied to the input data are described in HELCOM (2010b) and Korpinen *et al*. (2012). The concepts were subsequently developed further for parts of the North Sea area by the HARMONY project (Andersen *et al*. 2013), which also developed an assessment software (Stock 2016). The same methodology has also been used in the Mediterranean and the Black Sea (Micheli *et al*. 2013). Hence, the method used in the 'State of the Baltic Sea report' (HELCOM 2017a) is similar to the method applied in HELCOM (2010a). However, the assessment approach has been refined, with a focus on improving the data underlying the assessment, as presented in this chapter.

## 3.1 ASSESSMENT PROTOCOL

The key components of the BSII are georeferenced data sets of human induced pressures and ecosystem components, as well as sensitivity scores that are used in combining the pressure and ecosystem component layers. The sensitivity scores estimate the potential impact of each assessed pressure on each specific ecosystem component.

The assessment can also be applied with a focus on pressures only, producing the Baltic Sea Pressure Index (BSPI). The BSPI shows the cumulative anthropogenic pressures in the defined assessment units, without including impacts on ecosystem components.

Both the assessments were carried out at a Baltic Sea regional scale based on assessment units of 1 square kilometres (grid cells). The BSII was calculated based on the sum of all impacts in one assessment unit, for all ecosystem components (Figure 1, formula A). The method allows for including several ecosystem component layers per grid cell and is suitable when the underlying ecosystem component data sets have relatively high level of detail. The Baltic Sea Pressure Index was calculated by summing the pressure intensities in each assessment unit (Figure 1, formula B).

The general steps of the assessment protocol are outlined in Box 1.

A: Baltic Sea Impact Index

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

B: Baltic Sea 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). Cumulative pressures (S), which form the basis of the BSPI, were calculated without considering the ecosystem components (Formula D).

## Box 1. 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 most 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-building 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 are estimated by 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, but other graphs can be produced to visualize key results. 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.

## 3.2 CONFIDENCE IN THE ASSESSMENT

The confidence in the assessment is evaluated qualitatively, by evaluating the quality of the underlying components: the sensitivity scores and the spatial data sets. An evaluation of confidence in setting the sensitivity score is provided in Chapter 3.5. The quality of the underlying spatial layers can be evaluated by examining the underlying spatial data layers, available at the HELCOM maps and data service and the HELCOM Metadata catalogue (HELCOM 2017b, c).

The overall assessment outcome depends on the number of ecosystem components and pressures assessed in each grid cell. The highest impacts are often found in assessment units where several pressures and/or ecosystem components are present. Therefore, a high index score can either be explained by several pressures impacting at a site or by a single pressure if there are several ecosystem components that are sensitive to it. The relative role of the sensitivity scores in influencing the outcome is also higher if only a few layers are present in the assessment (Korpinen *et al.* 2012), however this was not the case in the present BSII assessment.

The Baltic Sea Impact Index is assessed based on the 'sum impact' (Figure 1, formula A) because this approach shows greater differences between more and less impacted areas. However, in cases where there are significant gaps in the underlying ecosystem component data sets, it may be more suitable to use the method of 'averaging' or 'maximum impact'. The 'averaging' method has recently been used in assessments in other sea areas (e.g. Halpern *et al.* 2015). The 'maximum impact' method might be appropriate to highlight areas of high risk, but is not commonly used when the results are displayed as maps.

## 3.3 INPUT PRESSURE DATA

The input data for the assessment were defined in order to have a balance in the number of data layers representing different types of anthropogenic pressures, since an unbalance was expected to lead to over-representation of data-rich sectors. Therefore, in the case of several original data sets representing the same pressure, these have been combined into aggregated pressure layers before inclusion in the analyses.

In all, 19 pressure layers were included in the assessment (Table 1). The pressure layers were aggregated based on information from 54 more specific spatial data sets on pressures and human activities. Most of the layers were derived directly from data representing observed levels of the pressure at sea, such as continuous sound, catches of fish, concentration of nutrients. In other cases, no direct measurements were possible and pressures were estimated based on information on the distribution and magnitude of human activities. The spatial data sets underlying each aggregate pressure layer are specified in Annex 1[5].

The organization of the pressure layers follows Annex III of the revised the Marine Strategy Framework Directive (EC 2017 a, b). Some modifications were applied to make the list applicable to Baltic Sea conditions. Human activities not occurring in the Baltic Sea were omitted, and some pressures were sub-divided as they were considered important for the region: fishing was subdivided into fishing on different species, hunting of seals and seabirds are assessed separately, and inputs of nitrogen and phosphorus are assessed separately. Climate change related pressures – acidification and changes in salinity and temperature - were not included due to a lack of approach for how to handle the monitoring data. Furthermore, data on the inputs of litter and organic matter were not included due to a lack of spatial information.

[5] Some of the layers will be subject to further processing in the updated 'State of the Baltic Sea' report by 2018, see Chapter 8 in the summary report (HELCOM 2017a).

Table 1. Pressure layers included in the assessment. For a more detailed description, see Annex 1.

| **Pressure type** | **Pressures** |
|---|---|
| Physical pressures | 1. Physical loss |
| | 2. Physical disturbance |
| | 3. Changes to hydrological conditions |
| Inputs of substances and energy | 4. Inputs of continuous anthropogenic sounds |
| | 5. Inputs of impulsive anthropogenic sound |
| | 6. Inputs of other form of energy |
| | 7. Input of heat |
| | 8. Inputs of hazardous substances |
| | 9. Inputs of nitrogen |
| | 10. Inputs of phosphorus |
| | 11. Introduction of radionuclides |
| | 12. Oil slicks and spills |
| | 13. Disturbance of species due to human presence |
| Biological pressures | 14. Fishing of herring |
| | 15. Fishing of cod |
| | 16. Fishing of sprat |
| | 17. Hunting and predator control of seabirds |
| | 18. Hunting of seals |
| | 19. Introduction of non-indigenous species |

The assessment builds on a linkage framework, which allows each pressure to be back-tracked to human activities potentially causing that pressure (Figure 2). The linkage framework underlying the BSII was compiled by the HELCOM TAPAS[6] and the BalticBOOST[7] projects, considering also results from previous cumulative impacts assessments (The ODEMM project[8], OSPAR[9], JNCC[10] and INPN[11]). The linkages are referred to as impact chains by Knights *et al*. (2013).

[6] The HELCOM coordinated EU co-finance project: Development of HELCOM tools and approaches for the Second Holistic Assessment of the Ecosystem Health of the Baltic Sea
[7] The HELCOM coordinated EU co-financed project: Baltic Sea project to boost regional coherence of marine strategies through improved data flow, assessments, and knowledge base for development of measures
[8] http://odemm.com/content/linkage-framework
[9] http://qsr2010.ospar.org/media/assessments/p00443_BA6_assessment-final.pdf
[10] http://jncc.defra.gov.uk/pdf/Final_HBDSEG_P-A_Matrix_Paper_28b_Website_edit%5b1%5d.pdf
[11] https://inpn.mnhn.fr/programme/sensibilite-ecologique?lg=en

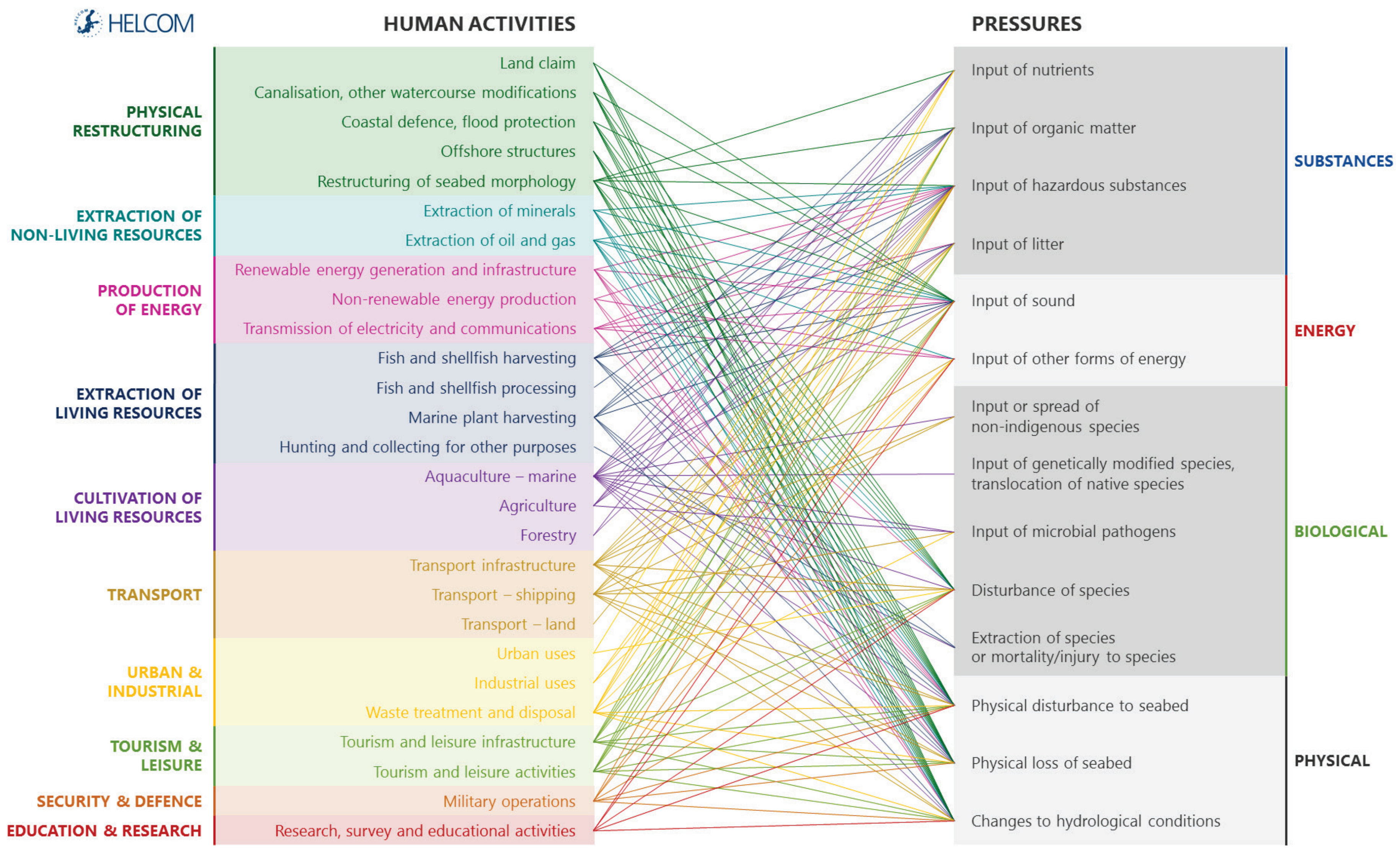


Figure 2. Human activities in the Baltic Sea and their connection to pressure types. The lines show which pressures are potentially induced by a certain human activity, without inferring the magnitude of the pressure in each case, nor its potential impacts on the environment. The figure illustrates the level of complexity potentially involved in the management of environmental pressures. From the 'State of the Baltic Sea' summary report (HELCOM 2017a, Chapter 3)Temporal aspects of pressures

The temporal extent of each pressure was taken into account when preparing the pressure layers. For pressures that are additive over time, or which last a long time (such as 'Physical loss of habitat'), the cumulative value for all years during the assessment period was used (2011-2016). For pressure that act more temporarily, annual averages over the assessment period were used (See Annex 1 for details).

## Spatial extent of the pressures

The pressure layers, and in some case the underlying spatial data sets, were further processed before use in order to better represent the likely extent of the human induced pressure at sea. The details for how this was applied are presented in Annex 1 and the approaches are summarized below.

*The spatial extent of a pressure* was estimated based on results from the TAPAS expert survey and from literature information (see chapter 3.5). The TAPAS expert survey was designed in order to inform the Baltic Sea Impact Index on the setting of sensitivity scores, and included a question on the likely spatial extents of each pressure (Annex 2). The respondents were also asked about the way in which the intensity of the pressure diminishes away from the source. And impact type with a steep decline near the source and then a more slowly declining response was most often identified (Annex 3).

For the physical pressure layers, the spatial extent information was based on a literature review by the BalticBOOST project. The literature review focused on human activities potentially causing physical pressures (physical loss, physical disturbance, changes to hydrological conditions; Annex 3). As these three physical pressure layers were derived based on spatial data sets on human activities, the spatial extents were applied already at the underlying human activity data sets before aggregating these to pressure layers (Annex 1).

## Effects of water depth and wave exposure

For some pressures layers, the intensity is affected by water depth or seabed wave exposure, and this was taken into account, where motivated. For physical disturbance caused by shipping (via resuspension) and biological disturbance caused by human activities taking place at the sea surface, the pressure values were down-weighted at higher depths. For physical disturbance caused by dredging, disposal of dredged matter and sand extraction, a Baltic-wide map of wave exposure at the seabed, obtained from the Finnish Environment Institute, was used to down-weight the pressure values in exposed areas (Annex 1).

## Approach for aggregating spatial data sets

In order to achieve a balanced representation of pressure types in the assessment, many pressure layers were aggregated from several underlying data sets. This aggregation was straightforward when the spatial data sets to be combined are measured by the same units. However, when the underlying data sets are measured in different units, or when they represent different features, a direct aggregation would fail to take into account differences in their magnitude. This was especially true for the pressure 'physical disturbance', which was based on information from tens of human activities, increasing the risk of overestimating the importance of some activities if their relative magnitude is not considered.

For the aggregation of such data sets, literature information was looked upon as a basis for ranking the relative magnitude of pressures from different human activities (Table 2). The human activities attributed to physical disturbance were categorized into each of five classes, representing different relative intensity of human-induced physical disturbance. The information was subsequently used as weighting factors when aggregating the spatial data sets on human activities into one pressure data layer. The weights were applied after normalizing (see Annex 1 for more details).

Table 2: Ranking and categorization of intensity of physical disturbance from different human activities.

| **Rank** | **Human activity** | **Weight** |
|---|---|---|
| High pressure intensity and/or slow recovery | Bottom-trawling, Demersal seining (Danish and Scottish), Demersal long-lining, Scallop and blue mussel dredging, Maintenance and capital dredging, Sediment disposal, Sand and gravel extraction | 1 |
| Moderate to high | Shipping and ferry traffic, Marinas, Gas pipelines | 0.8 |
| Moderate | Wind turbine construction | 0.6 |
| Low to moderate | Cables and small pipelines | 0.4 |
| Low | Boating, Wind turbines in operation | 0.2 |
| No pressure | | 0 |

## 3.4 INPUT DATA ON ECOSYSTEM COMPONENTS

For use in the BSII, a total of 36 ecosystem component layers were developed by support of the TAPAS project (Table 3). The layers were based on information obtained directly from the countries, enquires to the HELCOM expert projects and networks, and on EUSeaMap project for broad-scale habitats, as explained in the HELCOM map and data service (HELCOM 2017b) and HELCOM metadatabase (HELCOM 2017c)[12].

Table 3. Ecosystem component layers included in the assessment.

| **Ecosystem components** | |
|---|---|
| 1. Productive surface waters | 19. Coastal lagoons (1150) |
| 2. Oxygenated deep waters | 20. Large shallow inlets and bays (1160) |
| 3. Infralittoral hard bottom | 21. Reefs (1170) |
| 4. Infralittoral sand | 21. Submarine structures made by leaking gas (1180) |
| 5. Infralittoral mud | 22. Baltic Esker Islands (UW parts, 1610) |
| 6. Infralittoral mixed | 24. Boreal Baltic islets and small islands (UW parts, 1620) |
| 7. Circalittoral hard bottom | 25. Cod abundance |
| 8. Circalittoral sand | 26. Cod spawning area |
| 9. Circalittoral mud | 27. Herring abundance |
| 10. Circalittoral mixed | 28. Sprat abundance |
| 11. Furcellaria lumbricalis | 29. Recruitment areas of perch |
| 12. Zostera marina | 30. Recruitment areas of pikeperch |
| 13. Charophytes | 31. Wintering seabirds |
| 14. Mytilus edulis | 32. Breeding seabird colonies |
| 15. Fucus sp. | 33. Grey seal distribution |
| 16. Sandbanks which are slightly covered by sea water at all time (1110) | 34. Harbour seal distribution |
| 17. Estuaries (1130) | 35. Ringed seal distribution |
| 18. Mudflats and sandflats not covered by seawater at low tide (1140) | 36. Distribution of harbour porpoise |

12 Some of the layers may be subject to further processing in the updated 'State of the Baltic Sea' report by 2018.

# 3.5 SENSITIVITY SCORES

The development of the BSII sensitivity scores was based on an expert survey, which was submitted to Baltic Sea experts via HELCOM contact points. The results were compared with available literature information and the sensitivity scores finally applied in the assessment are presented in Annex 4.

## Overview of the expert survey

The expert survey was developed in the TAPAS project and was presented in Microsoft Excel, supplemented with guidance on how to respond to the survey (Annex 2).

The survey contained a matrix of all possible combinations of pressures and ecosystem components (see tables 1 and 3). Respondents were asked to provide estimates with respect to combinations of pressures and ecosystem components within their area of expertise, addressing six themes: 1) Tolerance/resistance, 2) Recoverability, 3) Sensitivity, 4) Impact distance, 5) Impact type and 6) Confidence.

Answers to the themes of tolerance/resistance, recoverability and sensitivity were given as categories 'high', 'moderate' and 'low' with the possibility to provide additional free text information. These were transformed to numeric scores from 0 to 2, where 'low' sensitivity and 'high' tolerance and recoverability received the score 0 (and 'high' sensitivity and 'low' tolerance and recoverability received the score 2). The sensitivity of a species or habitat to a pressure is a combination of its tolerance/resistance and recoverability, but the survey also asked directly about the sensitivity. After comparing the answers, the sensitivity scores were finally based on the answers regarding 'sensitivity' alone, whereas the responses to the themes 'tolerance/resistance' and 'recoverability' were analyzed to assess the level of consistency in the replies (Annex 2).

Information from the impact distance and impact type were used when designing the pressure layers (see Chapter 3.3). Predefined reply alternatives for the impact distances were 'local', '1 km', '5 km', '10 km', '20 km' and '> 50 km', but self-defined distances were also allowed. For the impact type, four basic response curves were given as alternatives (see Annex 2).

For the question on 'confidence', participants were asked to self-evaluate the confidence in their judgment. A 'low' confidence (score 1) was to be assigned if limited or no empirical documentation was available to support the judgement, so that the judgement was mainly based on inference from other, similar ecosystem components/pressure types or from knowledge on the physiology and ecology of the species, for example. A 'moderate' confidence (score 2) was to be assigned if empirical documentation was available, but results of different studies could be contradictory, or based on grey literature with limited scope. Finally, a 'high' confidence (score 4) was to be given if documentation was available with relatively high agreement among studies.

## Confidence of the sensitivity scores

The confidence in the results from the expert survey was assessed based on the number of replies, the variability among obtained responses, and the self-evaluation provided by the experts.

### *Number of replies*

A total of 81 persons from 9 countries responded to the survey (Table 4). Between 1 and 35 replies were provided to the different combinations. Only one response was given to the ecosystem component 'Submarine structures made by leaking gases'. The mean number of replies per pressure-ecosystem component combination was 12.1 with respect to 'tolerance' (standard deviation= 6.1), 11.8 for recoverability' (standard deviation = 6.1) and 11.4 for the theme 'sensitivity' (standard deviation = 5.7).

Table 4. 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** |

### *Variability in the obtained responses*

There was some variability in the scores provided by different experts to the same pressure and ecosystem component combination. The standard deviation from the mean for responses to a certain combination was on average 0.55, for 'tolerance' (ranging between 0 and 1), and 0.62 for 'recoverability' as well as 'sensitivity' (ranging between 0 and 1.41).

### *Self-evaluation by the experts*

The experts estimated the lowest confidence (on average 1.2) to the pressure 'Input of radionuclides'. Other pressures assessed with low confidence (below 2 on average) were '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 confidence was assessed in relation to impacts on 'Baltic esker islands' (1.8) and the highest confidence to 'Oxygenated deep waters' (2.5). In general, the variability in assessed confidence was lower among ecosystem components than among pressures. When looking at the sensitivity scores, the lowest confidence (1.0) was given to impact on the habitat 'Submarine structures made by leaking gas' from 'radionuclides', 'climate change' and 'acidification'. The highest average confidence score (3.4) was given in relation to impacts on roach from nutrient inputs. The overall variability in the confidence assessment was rather low (0.27-0.71 among ecosystem components and 0.19-0.50 among pressures).

## *Conclusions*

Combinations of pressures and ecosystem components assessed with reduced confidence, due to any of the above criteria, are listed in Table 5. These combinations are proposed to be revisited in time for the updated assessment. For the current assessment, the combinations with reduced confidence were checked against the obtained sensitivity scores. For combinations where the average sensitivity score was also low (0-1.0), the influence of these combinations on the assessment outcome is low. In one case, a moderate sensitivity score was observed in combination with reduced confidence (sensitivity of submarine structures to the oil spills)

Table 5. Combinations of pressures and ecosystem components where sensitivity scores in the expert survey had low confidence, according to three criteria: 1) Few replies obtained in the survey (less than 8), 2) high variability in responses from different experts (standard deviation above 1.0) or 3) low confidence in the assessment based on the self-evaluation from the experts (mean value below 1.5). The combinations are organized by pressures in alphabetical order. The reason for the combination being listed is explained in the last column. SD = Standard deviation. Pressures and ecosystem components marked * were not included in the Baltic Impact index.

| Pressure | Ecosystem component | Decisive confidence criterion |
|---|---|---|
| All | Submarine structures made by leaking gases | Few replies<br>(on average 3.5) |
| Many (numbers 4-6, 8, 11-19 in Table 1) | Baltic esker islands | Few replies<br>(on average 3.4) |
| Many (numbers 4-6, 8, 11-19 in Table 1) | Baltic Boreal islets | Few replies<br>(on average 3.2) |
| Acidification* | All | Few replies<br>(on average 5.5) |
| | Bird migration routes*, Grey seal haul-outs, Harbour seal haul-outs Grey seal abundance, Harbour seal abundance, Estuaries, Recruitment areas of pikeperch, Recruitment areas of roach | High variability<br>(SD from 1.0 to 1.4) |
| | Submarine structures made by leaking gases | Low assessed confidence<br>(on average 1.0) |

| | | |
|---|---|---|
| | Ringed seal distribution | Low assessed confidence (on average 1.4) |
| Changes in climatic conditions* | Baltic esker islands, Boreal Baltic islets, Submarine structures made by leaking gases | High variability (SD between 1.2 and 1.4) |
| | Mudflats and sandflats, Estuaries | Low assessed confidence (1.3 and 1.0, respectively) |
| | Grey seal haul-outs and Harbour seal haul-outs | Low assessed confidence (on average 1.4 in both cases) |
| Changes in hydrological conditions | Submarine structures made by leaking gases | Low assessed confidence (on average 1.3) |
| Extraction of /injury to mammals | Furcellaria lumbricalis and Charophytes | High variability (SD 1.2 in both cases |
| | Productive surface waters | High variability (SD 1.0) |
| | All habitats and all habitat-forming species | Few replies (on average 5.6) |
| Fishing mortality | Circalittoral hard bottom | High variability (SD 1.0) |
| | Productive surface waters | High variability (standard deviation 1.0) |
| Input of continuous sound | Baltic esker islands | Low assessed confidence (on average 1.4) |
| Input of hazardous substances | Submarine structures made by leaking gases | Low assessed confidence (on average 1.3) |
| | Mudflats and sandflats, Estuaries | Low assessed confidence (on average 1.4 in both cases) |
| Input of litter | Submarine structures made by leaking gases | Low assessed confidence (on average 1.2) |
| | Baltic esker islands, Boreal Baltic islets | Low assessed confidence (1.4 and 1.3, respectively) |
| | Breeding seabird colonies | Low assessed confidence (on average 1.4) |
| Input of other forms of energy | Baltic esker islands | Low assessed confidence (on average 1.4) |
| | All habitats and all habitat-forming species | Few replies (on average 6.5) |
| Inputs of radionuclides | Grey seal abundance and Harbour seal abundance | High variability (SD 1.0 in both cases) |
| | Many (34 of 40 ecosystem components) | Low assessed confidence (from 1.0 to 1.4) |
| Introduction of non-indigenous species | Distribution of harbour porpoise, Harbour seal haul-outs, Grey seal haul-outs, Migration routes for birds, Breeding seabirds colonies, Wintering seabirds, and Submarine structures made by leaking gas | Low assessed confidence (on average 1.2 to 1.4) |

| | | |
|---|---|---|
| Mammal mortality | Productive surface waters | High variability (SD 1.0) |
| Oil spills | Submarine structures made by leaking gases | Low assessed confidence (on average 1.3) |

## Literature information to assessed benthic habitats

Sensitivity scores to assess impacts on benthic habitats and species were also assessed by a literature review provided by the BalticBOOST project[13]. The literature review assessed the sensitivity of all kinds of benthic habitats to the pressures physical loss, physical disturbance and changes in hydrological conditions. The review suggested that the pressure 'physical loss' is given the highest sensitivity score in all cases. The literature that was used to suggests a sensitivity score for the pressure 'physical disturbance' is presented in table 6, and that for 'hydrological conditions' is presented in Table 7.

Literature to support the setting of sensitivity score of benthic habitats for other pressures, as well as other literature referred to, is given in Annex 4.

Table 6. Sensitivity of benthic habitats to physical disturbance pressure based on the literature review. The sensitivities are estimated based on activities causing impacts and the recovery time. Final sensitivity scores are given in Annex 4.

| **Benthic habitat** | | **Reported impacts** | **Recovery** | **Sensitivity category** | **References** |
|---|---|---|---|---|---|
| **Broad-scale seabed habitats** | | | | | |
| Infralittoral hard bottom | | Strong siltation impacts. | >4 years, depends on shore exposure | High | Essink 1999, Vahteri & Vuorinen 2001, Oulasvirta & Leinikki 2003, Kotta *et al.* 2009 |
| Infralittoral sand | | Intermediate-high siltation impacts on eelgrass | >2-6 years | High | 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 | 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 | Essink 1999 |

[13] The HELCOM coordinated EU co-financed project: Baltic Sea project to boost regional coherence of marine strategies through improved data flow, assessments, and knowledge base for development of measures

| | | | | | |
|---|---|---|---|---|---|
| Circalittoral sand | | Macrofauna effects after modification are strong and recovery is long. | 0.5-4 years | High | 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 | Moderate | 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 spp. | | 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 |

Table 7. Sensitivity of benthic habitats to 'Changes in hydrographical conditions' based on the literature review. The sensitivities are estimated based on activities causing impacts. Final sensitivity scores are given in Annex 4.

| Benthic habitat | Reported impacts | Sensitivity category | 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 | Moderate | Martin *et al.* 2005, Eastwood *et al.* 2007 |

| | | | |
|---|---|---|---|
| | installation changes seabed morphology and substrate. | | |
| Infralittoral mud | Accumulation of finer sediments to landward side of coastal structures -> biological change. Abrasion around an installation changes seabed morphology and substrate. | Moderate | 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 | | |

## Sensitivity scores applied in the Baltic Sea Impact Index

The information from the expert survey and literature studies were considered in the setting of impact scores as explained in Annex 4.The scores that were applied are presented in Table 8.

**Table 8. Sensitivity scores applied in the Baltic Sea Impact Index.** Note that the sensitivity scores of the broad habitat layers 'Infralittoral mixed' and 'Circalittoral mixed' were produced as means of the other three layers as part of the processing. The full explanation to the pressure layers is given in report Table 1 and Annex 1. The Scores are color-coded so that higher scores are red, intermediate scores white and low scores blue. The pressures and ecosystem components are sorted so that the highest scores appear in the upper left and the lowest scores appear in the lower right part of the table.

| **Sensitivity scores: mean** | **12. Oil slicks and spills** | **1. Physical loss** | **2. Physical disturbance** | **9. Inputs of nitrogen** | **10. Inputs of phosphorus** | **3. Changes to hydrological conditions** | **14. Extraction of, herring** | **15 Extraction of, cod** | **16. Extraction of, sprat** | **8. Inputs of hazardous substances** | **19. Introduction of non-indigenous species** | **13. Disturbance of species** | **7. Input of heat** | **17. Hunting of seabirds** | **18. Hunting of seals** | **5. Inputs of impulsive sound** | **4. Inputs of continuous sounds** | **6. Inputs of electromag-netic and seismic waves** | **11. Introduction of radionuclides** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21. Submarine structures made by leaking gas (1180) | 1.8 | 1.7 | 1.2 | 1.6 | 1.6 | 1.3 | 0.8 | 0.8 | 0.8 | 0.7 | 1.4 | 1.0 | 1.0 | 1.5 | 1.5 | 1.0 | 1.0 | 1.0 | 0.5 |
| 17. Estuaries (1130) | 1.6 | 1.8 | 1.6 | 1.4 | 1.4 | 1.5 | 1.1 | 1.1 | 1.1 | 0.8 | 1.3 | 1.0 | 0.9 | 0.8 | 0.8 | 0.9 | 0.8 | 0.8 | 0.7 |
| 19. Coastal lagoons (1150) | 1.7 | 1.9 | 1.7 | 1.5 | 1.5 | 1.6 | 1.1 | 1.1 | 1.1 | 1.0 | 1.4 | 1.0 | 1.3 | 0.6 | 0.6 | 0.8 | 0.7 | 0.6 | 0.2 |
| 12. Zostera marina | 1.6 | 1.9 | 1.9 | 1.9 | 1.9 | 1.7 | 0.9 | 0.9 | 0.9 | 0.9 | 1.1 | 1.2 | 1.6 | 0.8 | 0.8 | 0.1 | 0.2 | 0.5 | 0.6 |
| 41. Ringed seal distribution | 1.4 | 0.5 | 0.6 | 0.5 | 0.5 | 0.6 | 1.5 | 1.5 | 1.5 | 1.4 | 1.1 | 1.2 | 0.6 | 1.6 | 1.6 | 1.6 | 1.5 | 0.4 | 1.2 |
| 20. Large shallow inlets and bays (1160) | 1.6 | 1.8 | 1.6 | 1.3 | 1.3 | 1.3 | 1.1 | 1.1 | 1.1 | 0.7 | 1.3 | 0.9 | 1.2 | 0.7 | 0.7 | 0.9 | 0.8 | 0.8 | 0.2 |
| 21. Reefs (1170) | 1.9 | 2.0 | 1.6 | 1.3 | 1.3 | 1.4 | 0.9 | 0.9 | 0.9 | 1.2 | 1.2 | 0.8 | 1.0 | 1.1 | 1.1 | 0.3 | 0.3 | 0.6 | 0.6 |
| 39. Harbour seal abundance | 1.6 | 0.6 | 0.7 | 0.3 | 0.3 | 0.7 | 1.2 | 1.2 | 1.2 | 1.5 | 0.8 | 1.3 | 0.3 | 1.9 | 1.9 | 1.6 | 1.5 | 0.6 | 1.0 |
| 18. Mudflats and sandflats not covered by seawater at low tide (1140) | 1.8 | 1.9 | 1.7 | 1.5 | 1.5 | 1.8 | 0.9 | 0.9 | 0.9 | 0.6 | 0.9 | 1.0 | 1.7 | 0.8 | 0.8 | 0.2 | 0.2 | 0.5 | 0.3 |
| 29. Distribution of demersal spawning flounder | 1.3 | 1.7 | 1.3 | 1.6 | 1.6 | 0.8 | 1.8 | 1.8 | 1.8 | 0.8 | 0.9 | 1.0 | 0.7 | 0.3 | 0.3 | 0.7 | 0.2 | 0.6 | 0.5 |
| 32. Recruitment areas of pikeperch | 1.7 | 1.6 | 1.1 | 0.7 | 0.7 | 1.2 | 2.0 | 2.0 | 2.0 | 0.6 | 0.9 | 1.0 | 0.3 | 0.5 | 0.5 | 1.1 | 0.6 | 0.7 | 0.5 |
| 16. Sandbanks which are slightly covered by sea water at all time (1110) | 1.5 | 1.9 | 1.6 | 1.5 | 1.5 | 1.3 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 1.1 | 0.9 | 1.0 | 1.0 | 0.2 | 0.2 | 0.5 | 0.4 |
| 11. Furcellaria lumbricalis | 1.5 | 1.9 | 1.7 | 1.5 | 1.5 | 1.7 | 0.7 | 0.7 | 0.7 | 0.9 | 1.2 | 0.6 | 1.5 | 0.7 | 0.7 | 0.3 | 0.2 | 0.6 | 0.5 |
| 40. Harbour seal haulouts | 1.6 | 0.8 | 0.9 | 0.3 | 0.3 | 0.6 | 1.0 | 1.0 | 1.0 | 1.6 | 0.5 | 1.6 | 0.2 | 2.0 | 2.0 | 1.5 | 1.5 | 0.3 | 0.3 |
| 31. Recruitment areas of perch | 1.6 | 1.6 | 1.3 | 1.4 | 1.4 | 1.2 | 1.6 | 1.6 | 1.6 | 0.4 | 1.0 | 1.3 | 0.4 | 0.0 | 0.0 | 0.9 | 0.4 | 0.7 | 0.4 |
| 37. Grey seal abundance | 1.3 | 0.6 | 0.7 | 0.3 | 0.3 | 0.7 | 1.2 | 1.2 | 1.2 | 1.4 | 0.8 | 1.0 | 0.3 | 1.6 | 1.6 | 1.6 | 1.4 | 0.6 | 1.0 |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13. Charophytes | 1.5 | 1.9 | 1.9 | 1.7 | 1.7 | 1.4 | 0.8 | 0.8 | 0.8 | 0.8 | 1.4 | 0.7 | 0.9 | 0.7 | 0.7 | 0.0 | 0.0 | 0.6 | 0.4 |
| 7. Circalittoral hard bottom | 1.3 | 1.9 | 1.3 | 1.3 | 1.3 | 1.4 | 0.8 | 0.8 | 0.8 | 1.2 | 1.2 | 0.4 | 1.2 | 1.0 | 1.0 | 0.3 | 0.3 | 0.6 | 0.5 |
| 38. Grey seal haulouts | 1.4 | 0.8 | 0.9 | 0.3 | 0.3 | 0.6 | 1.0 | 1.0 | 1.0 | 1.6 | 0.5 | 1.4 | 0.2 | 2.0 | 2.0 | 1.5 | 1.5 | 0.3 | 0.3 |
| 34. Wintering seabirds | 2.0 | 0.9 | 0.8 | 0.2 | 0.2 | 0.5 | 1.1 | 1.1 | 1.1 | 1.4 | 0.6 | 1.3 | 0.4 | 1.7 | 1.7 | 0.9 | 0.8 | 0.6 | 0.7 |
| 42. Distribution of harbour porpoise | 1.6 | 1.2 | 1.3 | 0.2 | 0.2 | 0.4 | 1.5 | 1.5 | 1.5 | 1.6 | 0.4 | 1.2 | 0.5 | 0.0 | 0.0 | 1.9 | 1.7 | 0.3 | 1.0 |
| 22. Baltic Esker Islands (UW parts, 1610) | 1.6 | 1.8 | 1.5 | 1.3 | 1.3 | 1.3 | 0.8 | 0.8 | 0.8 | 0.8 | 1.3 | 0.7 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 |
| 33. Recruitment areas of roach | 1.7 | 1.7 | 1.1 | 0.5 | 0.5 | 1.2 | 1.6 | 1.6 | 1.6 | 0.6 | 0.9 | 0.8 | 0.3 | 0.5 | 0.5 | 1.0 | 0.6 | 0.4 | 0.5 |
| 24. Boreal Baltic islets and small islands (UW parts, 1620) | 1.6 | 1.8 | 1.5 | 1.2 | 1.2 | 1.1 | 0.8 | 0.8 | 0.8 | 0.8 | 1.3 | 0.7 | 1.0 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.1 |
| 35. Breeding seabird colonies | 2.0 | 0.9 | 0.9 | 0.3 | 0.3 | 0.4 | 1.0 | 1.0 | 1.0 | 1.3 | 0.8 | 1.8 | 0.3 | 1.6 | 1.6 | 0.8 | 0.6 | 0.3 | 0.2 |
| 30. Abundance of pelagic spawning flounder | 1.1 | 1.0 | 0.8 | 1.3 | 1.3 | 0.9 | 1.8 | 1.8 | 1.8 | 0.7 | 0.8 | 0.9 | 0.8 | 0.0 | 0.0 | 0.7 | 0.3 | 0.6 | 0.4 |
| 25. Cod abundance | 0.5 | 1.0 | 0.7 | 1.5 | 1.5 | 0.4 | 1.6 | 1.6 | 1.6 | 0.8 | 0.6 | 0.9 | 0.7 | 0.7 | 0.7 | 0.9 | 0.2 | 0.5 | 0.6 |
| 3. Infralittoral hard bottom | 1.7 | 1.8 | 1.3 | 1.3 | 1.3 | 1.2 | 0.6 | 0.6 | 0.6 | 1.0 | 1.1 | 0.3 | 1.3 | 0.7 | 0.7 | 0.2 | 0.2 | 0.6 | 0.4 |
| 15. Fucus sp. | 1.4 | 1.8 | 1.7 | 1.3 | 1.3 | 1.3 | 0.5 | 0.5 | 0.5 | 0.9 | 1.2 | 0.6 | 1.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.5 | 0.5 |
| 26. Cod spawning area | 1.0 | 0.7 | 0.8 | 1.7 | 1.7 | 0.9 | 1.3 | 1.3 | 1.3 | 0.9 | 0.4 | 0.6 | 0.6 | 0.2 | 0.2 | 1.0 | 0.6 | 0.5 | 0.5 |
| 1. Productive surface waters | 1.4 | 0.4 | 1.0 | 1.5 | 1.5 | 0.6 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 0.8 | 1.0 | 0.5 | 0.5 | 0.6 | 0.6 | 0.4 | 0.0 |
| 10. Circalittoral mixed | 1.1 | 1.8 | 1.1 | 1.2 | 1.2 | 1.3 | 0.6 | 0.6 | 0.6 | 1.0 | 1.0 | 0.4 | 0.9 | 0.7 | 0.7 | 0.3 | 0.3 | 0.6 | 0.4 |
| 6. Infralittoral mixed | 1.5 | 1.8 | 1.2 | 1.3 | 1.3 | 1.1 | 0.4 | 0.4 | 0.4 | 1.0 | 1.0 | 0.3 | 1.1 | 0.7 | 0.7 | 0.3 | 0.3 | 0.6 | 0.3 |
| 9. Circalittoral mud | 1.1 | 1.6 | 1.0 | 1.2 | 1.2 | 1.3 | 0.6 | 0.6 | 0.6 | 1.0 | 0.9 | 0.4 | 0.9 | 0.5 | 0.5 | 0.3 | 0.3 | 0.8 | 0.5 |
| 14. Mytilus edulis | 1.6 | 1.8 | 1.6 | 0.9 | 0.9 | 1.6 | 0.4 | 0.4 | 0.4 | 1.1 | 1.4 | 0.4 | 1.0 | 0.2 | 0.2 | 0.1 | 0.2 | 0.5 | 0.5 |
| 5. Infralittoral mud | 1.4 | 1.7 | 1.1 | 1.3 | 1.3 | 1.1 | 0.3 | 0.3 | 0.3 | 1.0 | 0.9 | 0.4 | 1.0 | 0.7 | 0.7 | 0.3 | 0.3 | 0.6 | 0.4 |
| 36. Migration routes for birds | 1.9 | 0.8 | 0.5 | 0.2 | 0.2 | 0.4 | 0.7 | 0.7 | 0.7 | 1.2 | 0.3 | 1.4 | 0.6 | 1.8 | 1.8 | 0.8 | 0.7 | 0.0 | 0.0 |
| 4. Infralittoral sand | 1.4 | 1.8 | 1.2 | 1.3 | 1.3 | 0.9 | 0.3 | 0.3 | 0.3 | 0.9 | 0.9 | 0.3 | 1.0 | 0.7 | 0.7 | 0.3 | 0.3 | 0.5 | 0.2 |
| 2. Oxygenated deep waters | 1.0 | 0.9 | 0.7 | 1.8 | 1.8 | 1.3 | 0.7 | 0.7 | 0.7 | 0.9 | 0.7 | 0.2 | 0.6 | 0.3 | 0.3 | 0.6 | 0.5 | 0.5 | 0.0 |
| 8. Circalittoral sand | 0.9 | 1.8 | 1.1 | 1.2 | 1.2 | 1.1 | 0.3 | 0.3 | 0.3 | 0.9 | 1.0 | 0.3 | 0.7 | 0.7 | 0.7 | 0.3 | 0.2 | 0.5 | 0.2 |
| 27. Herring abundance | 0.9 | 0.9 | 0.7 | 0.7 | 0.7 | 0.7 | 1.2 | 1.2 | 1.2 | 0.4 | 0.6 | 0.4 | 0.6 | 0.2 | 0.2 | 1.1 | 0.6 | 0.5 | 0.3 |
| 28. Sprat abundance | 0.9 | 0.5 | 0.5 | 0.6 | 0.6 | 0.7 | 1.2 | 1.2 | 1.2 | 0.4 | 0.6 | 0.4 | 0.6 | 0.2 | 0.2 | 1.1 | 0.6 | 0.5 | 0.3 |

# Chapter 4. Results

## 4.1. CUMULATIVE PRESSURES IN THE BALTIC SEA AREA

Although human activities take place almost everywhere in the Baltic Sea, they are mainly concentrated near the coast and close to urban areas. The distribution of potential cumulative pressures from human activities across the Baltic Sea becomes evident in the Baltic Sea Pressure Index (Figure 3). The most widely distributed pressures at regional scale were nutrient inputs, extraction of fish, underwater sound, contamination, and non-indigenous species.

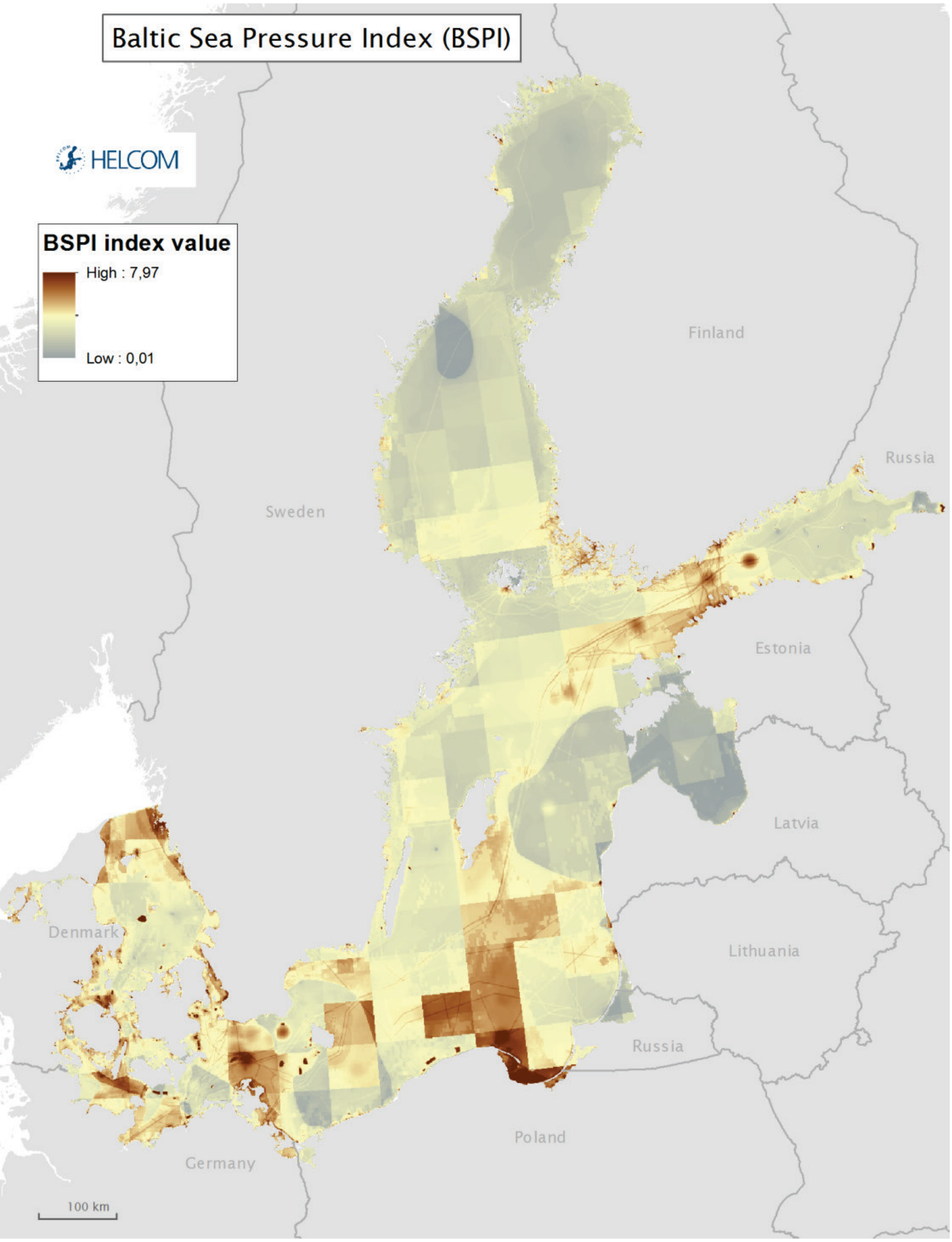


Figure 3. Baltic Sea Pressure Index showing distribution of potential cumulative pressures at sea. The Baltic Sea Pressure Index is an estimation of potential pressures based on currently best available regional data, but spatial and temporal gaps may occur in the underlying datasets.

## 4.2. CUMULATIVE IMPACTS IN THE BALTIC SEA MARINE AREA

The assessment of potential cumulative impacts indicates that there are great differences in the level of cumulative impacts between different areas of the Baltic Sea. The southwest areas and many coastal areas experience higher potential cumulative impacts than the northern areas and many open sea areas (Figure 4). However in areas with poor data coverage the potential cumulative impacts may be underestimated.

The pressures potentially responsible for causing most impacts in the Baltic Sea region were inputs of nutrients, contamination, continuous sound and non-indigenous species as well as extraction of fish (Figure XX). These are also the pressures which are most widely distributed in the Baltic Sea, and all the species and habitats have sensitivity to these pressures. Other pressures that were associated with high sensitivity scores, had lesser influence to the overall regional scale as they were not as widely distributed (Figure 5).

By considering the spatial distribution of species and habitats with respect to how they overlap spatially with different pressures, the Baltic Sea impact index identifies the species and habitats that are potentially most impacted overall. The most widely impacted ecosystem components (species or habitats) in the Baltic Sea were the water-column habitats which cover the entire sea area (deep water and surface water), the widely distributed benthic circalittoral habitats, and the marine mammals (Figure 5).

Shallow vegetated habitats were typically estimated as sensitive to several pressures and therefore the cumulative impacts were especially high in the coastal sea areas. In addition, more ecosystem component layers were represented in coastal areas compared to the open sea (for example macrophytes and blue mussel), which generated higher impact index values (Figure 4). Due to the large scale of impact values obtained (large difference between maximum and minimum values) in the Baltic Sea Impact index, areas subject to low and medium impact may be hard to differentiate in Figure 4 creating an impression of widely undisturbed areas, especially in the open basins of the Baltic Sea.

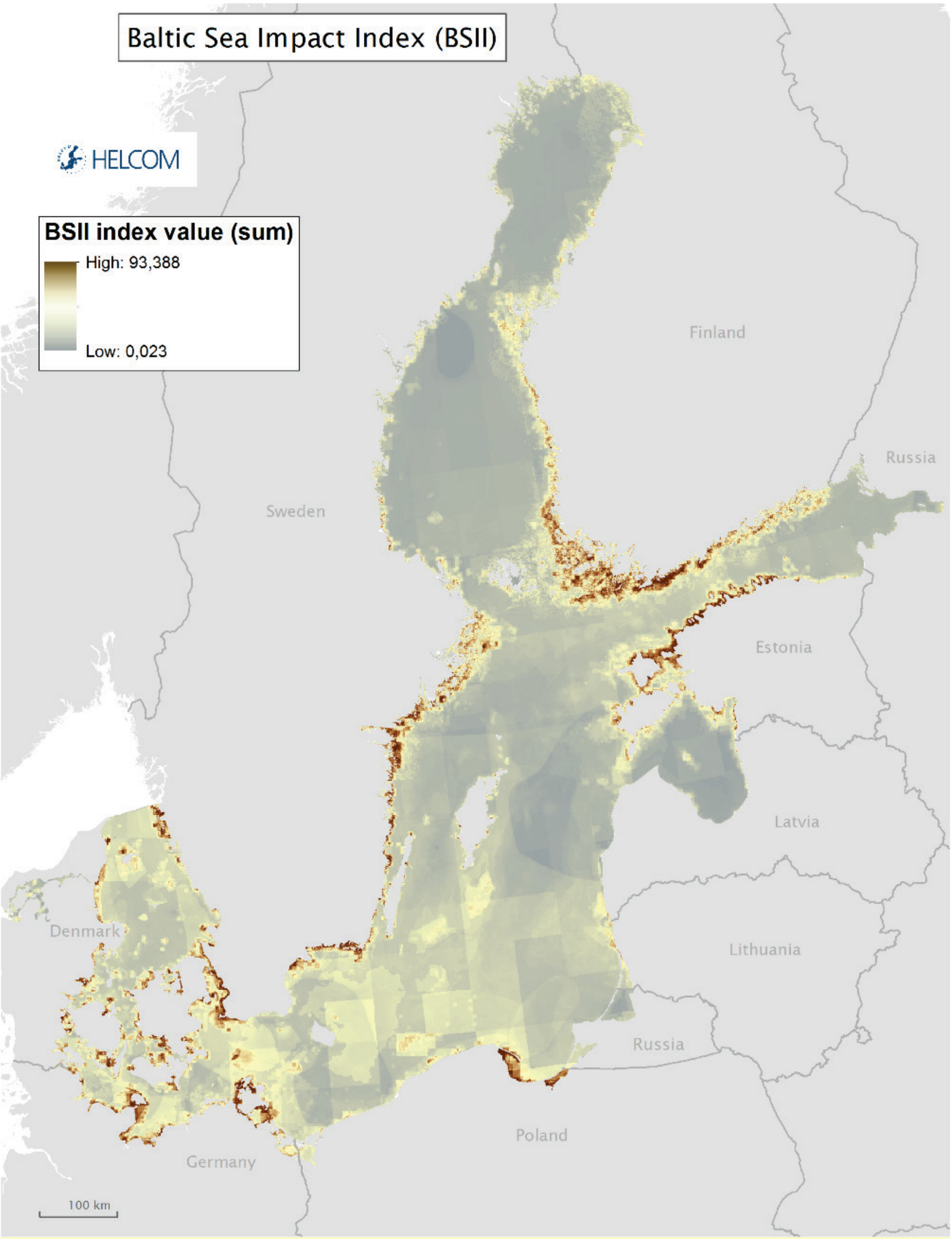


Figure 4. Map of the cumulative impacts of anthropogenic pressures based on the Baltic Sea Impact index. The cumulative impacts are calculated based on the method of the Baltic Sea Impact Index as the 'sum of impact'. The Baltic Sea Impact Index is an estimation of cumulative impacts based on currently best available regional data, but spatial and temporal gaps may occur in underlying datasets.

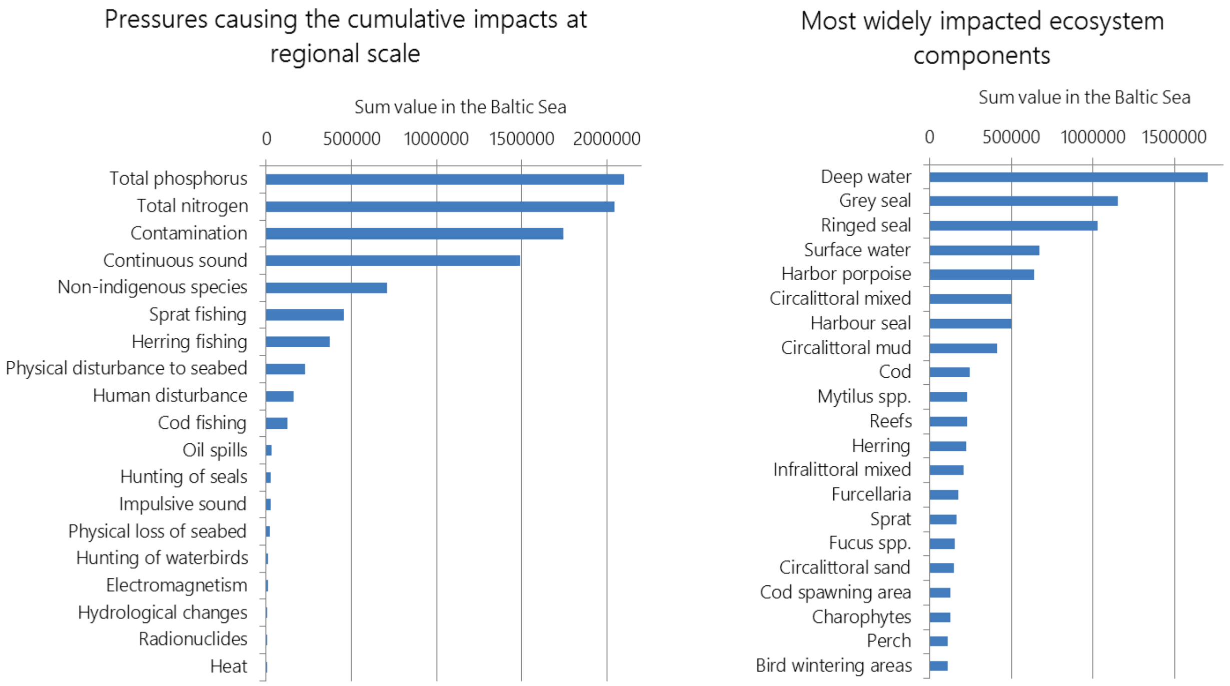


**Figure 5. Ranking of pressures causing the cumulative impacts at regional scale (left panel) and list of most widely impacted ecosystem components (species or habitats; right panel).** Note that the least impacted ecosystem components are not shown. The 'sum value' for pressures is calculated as the sum of impacts from each pressure on all studied ecosystem components at Baltic Sea scale. For ecosystem components it is calculated as the sum of impacts from all pressures on the each ecosystem component.

## 4.3. CUMULATIVE IMPACTS ON BENTHIC HABITATS

A separate analysis was carried out for potential cumulative impacts on the benthic habitats only, as these are particularly affected by physical pressures. In this case the evaluation was based on pressure layers representing physical loss and physical disturbance to the seabed, combined with information on the distribution of eight broad benthic habitat types and five habitat-forming species[14].

The evaluation suggests that benthic habitats are potentially impacted by loss and disturbance in all sub-basins of the Baltic Sea, but the highest estimates were found for coastal areas and in the southern Baltic Sea (Figure 6). The most impacted sub-basins were identified as the Kiel Bay, the Sound and the Bay of Mecklenburg (Figure 7). As the shallow waters usually host more diverse habitats, the impacts also accumulate more in coastal areas.

The human activities behind the cumulative impacts on benthic habitats, according to this assessment, are bottom trawling, shipping and sediment dispersal caused by various construction and dredging activities and disposal of the dredged sediment.

14 list of these to be added

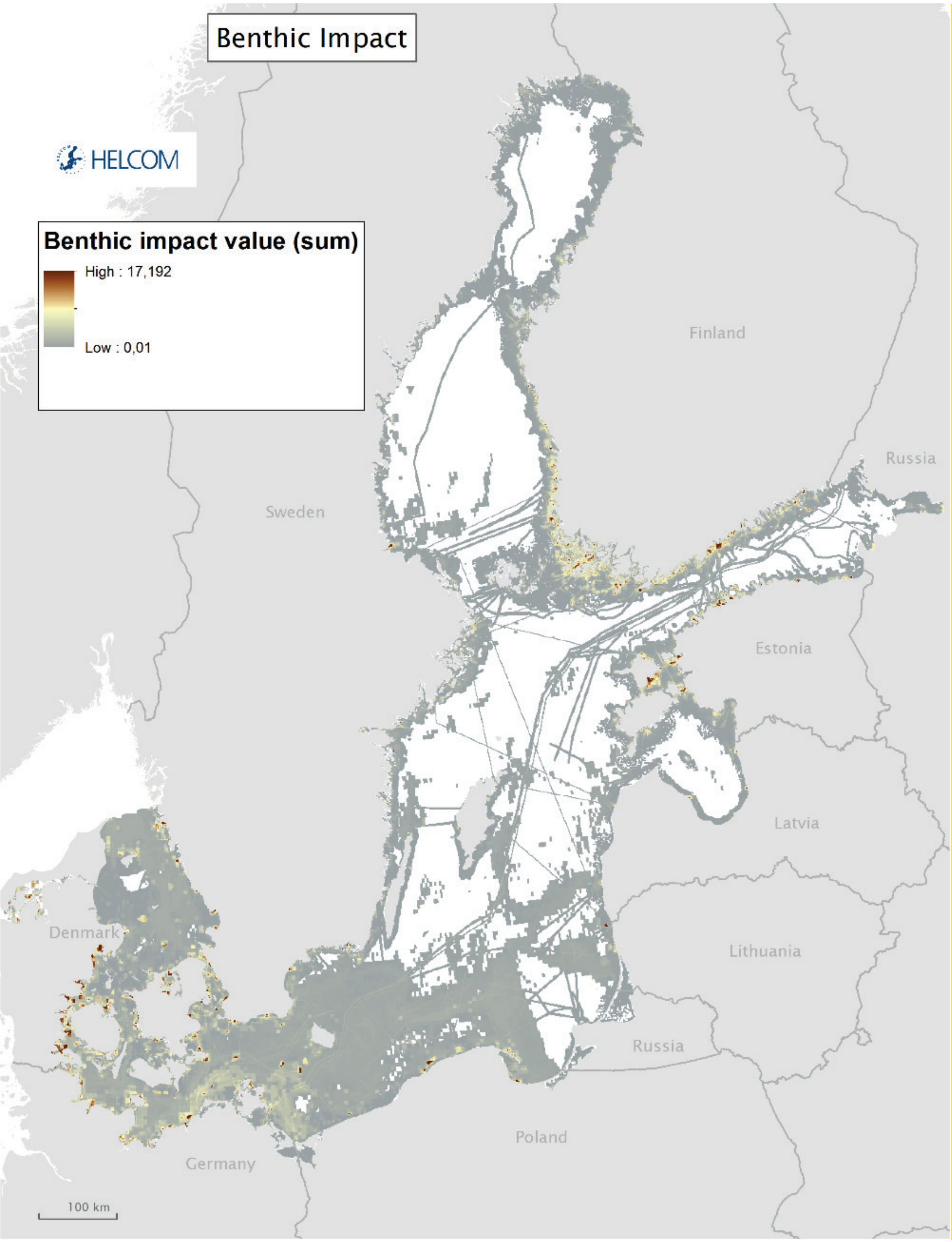


Figure 6. Map of potential cumulative impacts on benthic habitats in the Baltic Sea. The cumulative impacts are calculated based on the method of the Baltic Sea Impact Index as the 'sum of impact', specifically for the two pressures 'physical loss' and 'physical disturbance. Benthic habitats were represented by eight broad scale habitat types and five habitat forming species (*Furcellaria lumbricalis*, *Zostera marina*, *Mytilus edulis*, *Fucus* spp. and Charophytes). The cumulative impact has been estimated based on currently best available data, but spatial and temporal gaps may occur in underlying datasets. Areas in white in the map are not covered by any of the pressures associated with impact on the seabed.

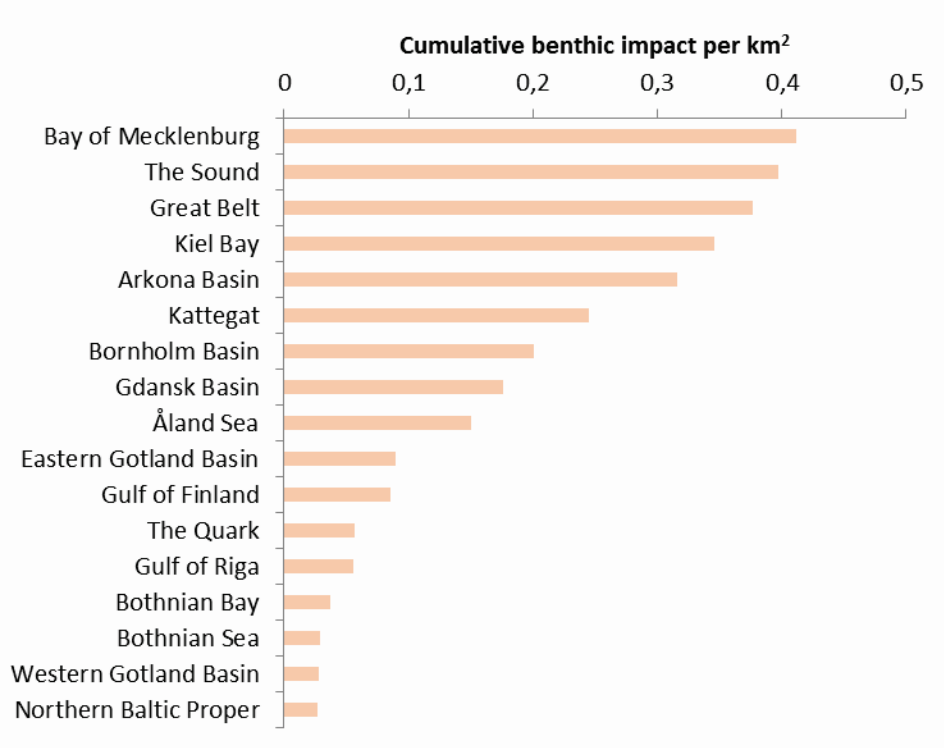


Figure 7. Cumulative impacts on benthic habitats in the Baltic Sea sub-basins. The values are calculated as the 'sum of impact' from physical loss and physical disturbance on the studied benthic habitat types and habitat forming species, divided by the area of the sub-basin. The estimates are based on currently best available regional data, but spatial and temporal gaps may occur in underlying datasets.

## 4.4. CONFIDENCE IN THE ASSESSMENT

The assessments of cumulative pressures and impacts are both directly dependent on the quality of the underlying data layers. The aim has been to collect and collate spatial information that is regional, so that the results will be comparable across areas.

In some cases, it has not been possible to achieve data sets with full spatial coverage, but layers have still been included in order to reflect the currently best available knowledge at regional scale. This concerns in particular data layers on impulsive noise, contamination, dredging and habitat-forming species.

Further, the level of spatial detail of individual data layers vary. While some maps provide information on a relatively detailed spatial scale, other layers are at present not detailed enough to be relevant at a more local scale, for example those showing species distributions.

There is also some remaining uncertainty regarding the applied impact scores, as the number of replies for some combinations of pressures and ecosystem components was low in the expert survey (Table 5).

Thus, the focus of the assessment is to give a broad regional overview, whereas the level of accuracy in detailed results need to be evaluated on a case by case basis. The input data may be further improved before the updated version of this report (due in June 2018), in cases where new information becomes available (See also Chapter 7 of the summary report: HELCOM 2017a).

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# Annex 1. Detailed description of the input data for the pressure layers

Aggregation rules (column B, G) to aggregate the pressure/human activity data sets (column C) to the aggregated pressure types (column A). Each pressure data layer in column C were processed to get a pressure value (column E) and a spatial extent (column D). Down-weighting by seabed exposure and water depth is described in column F.

| A. Aggregated pressure | B. Temporal nature | C. Spatial datasets to be combined | D. Spatial extent | Reference | 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 | Estimated on the basis of wind farm erosion protection (van der Wal & Tamis 2014). No direct reference. | Calculate area lost. In a grid cell: calculate proportion of the cell area. | Not relevant | Activities are combined and potentially overlapping areas are removed. Combined layer is intersected with 1 km grid to calculate % of area lost within a cell. |
| | | Watercourse modification | 50 m buffer | Estimated on the basis of wind farm erosion protection (van der Wal & Tamis 2014). No direct reference. | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Coastal defence and flood protection | 50 m buffer for lines, 100 m buffer for points | Estimated on the basis of wind farm erosion protection (van der Wal & Tamis 2014). No direct reference. | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Extraction of sand and gravel | area of polygon | - | Calculate area lost. In a grid cell: calculate proportion of the cell area. | Exposure affects recovery, but this is not included | |
| | | Dredging (capital and maintenance) (dataset was not included in the aggregated pressure layer "Physical loss" at this time, but will be | area of polygon or a 25/50 m buffer for <5000 m3 / >5000m3 sites | - | Calculate area lost (polygon/buffer) | Exposure affects recovery, but this is not included | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | included in the updated version in 2018) | | | | | |
| | | Deposition of dredged material (dataset was not included in the aggregated pressure layer “Physical loss” at this time, but will be included in the updated version in 2018) | 500 m buffer | - | Calculate area lost (polygon/buffer) | Exposure affects recovery, but this is not included | |
| | | Oil platforms | 25 m buffer | Estimated on the basis of wind farm erosion protection (van der Wal & Tamis 2014). No direct reference. | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Pipelines | 15 m  buffer | Between cables and wind farms | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Wind farms | 30 m buffer around each turbine | van der Wal & Tamis 2014 | Calculate area lost. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Cables | 1.5 m buffer | Estimate based on side-scan sonar photos (BalticBOOST case study in Mecklenburg Bight) | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Harbours | polygon with 200 m buffer | Orviku et al. 2008; and references in Maintenance dredging | Calculate area lost. In a grid cell: calculate proportion of the cell area. | Not relevant | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Marinas and leisure harbours | point with 200 m buffer | Eriksson et al. 2004, Sandström et al. 2005 | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Bridges | 2 m buffer | Estimate by TAPAS project based on erosion protection | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Bathing sites, beaches | 300 m buffer | Estimate by TAPAS project based on typical beach width towards sea. | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Oil terminals, refineries | point with 200 m buffer | Based on harbours (Orviku et al. 2008) | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Finfish mariculture | 150 m buffer | Leskinen et al. 1986 | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| | | Shellfish mariculture | area of polygon | - | Calculate lost area. In a grid cell: calculate proportion of the cell area. | Not relevant | |
| 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. No spatial impact outside grid cells. | See also Table 4 | Average of total shipping density in a 1km x 1 km cell 2011-2014, log-transformed, normalized. | rescaled with depth:<br>0-10 m= 100%<br>10-15 m= 50%<br>15-20 m= 25%<br>20-25 m= 10%<br>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 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Recreational boating and sports | Total fuel consumption of recreational boats modelled directly to 1 km grid cells. No spatial impact outside grid cells. | See also Table 4 | 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:<br>0-5m= 100%<br>5-7 m= 70%<br>7-10 m= 50%<br>10-15 m= 10%<br>15m < =0% | 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. |
| | | Extraction of sand and gravel | 3 km buffer with sharp decline after 0.5 km (type D decline) | See Table 4 for extent and Table 3 for the decline | 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 | 3 km buffer with sharp decline after 0.5 km (type D decline). Converted first to 100 m$^2$ and then to 1 km$^2$ grid cells. | See Table 4 for extent and Table 3 for the decline | 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 | 3 km buffer with sharp decline after 0.5 km (type D decline). . converted first to 100 m$^2$ and then to 1 km$^2$ grid cells | See Table 4 for extent and Table 3 for the decline | 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 around point data. | Based on 'Deposit of dredged material', but reduced extent. | Amount of bathing sites in a cell, normalized | Not relevant | |
| | | Wind farms (construction) | 1 km buffer with sharp decline after 0.5 km for windfarms under construction, | See Table 4 for extent and Table 3 for the decline | Number of wind farms under construction per grid cell | Weighted by the exposure map | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | polygon data converted first to 100 $m^2$ and then to 1 $km^2$ grid cells. | | | | |
| | | Wind farms (operational) | 0.1 km buffer with sharp decline. | See Table 4 for extent and Table 3 for the decline | Number of operational wind farms per grid cell | Not relevant | |
| | | Cables (construction) | 1 km buffer with sharp decline after 0.5 km for cables under construction, line data converted first to 100 $m^2$ and then to 1 $km^2$ grid cells | See Table 4 for extent and Table 3 for the decline | Presence of constructed cables, intensity scaled by their area in the grid cell | Weighted by the exposure map | |
| | | Pipelines (operational) | 0.3 km buffer with linear decline. | Based on the operational wind farms (see Table 4) | Presence of operational pipelines, intensity scales by their area in the grid cell | | |
| | | Fishing intensity (subsurface swept area ratio average 2011-2013) | 0.05 x 0.05 c-square degree grid (reporting unit for VMS data from ICES) | - | Average subsurface swept area ratio average 2011-2013, converted to 1x1km raster grid | Not relevant | |
| | | Watercourse 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 with sharp decline, point and line data converted first to 100$m^2$ and then to 1 $km^2$ grid cells | See Tables 3 and 4, extent based on wind farms and cables. | Area of coastal defence and flood protection under construction. | Weighted by the exposure map | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Finfish mariculture | **1 km buffer linear decline**, point data converted first to 100 $m^2$ and then to 1 $km^2$ grid cells | Based on 'Disposal of dredged material'. | Average P load 2011-2015, if values missing 25% percentile was given, normalized | Weighted by the exposure map | |
| | | Shellfish mariculture | **1 km buffer linear decline**, polygon data converted first to 100 $m^2$and then to 1 $km^2$ grid cells | Based on 'Disosal of dredged material'. | Average production in 2011-2015, if values missing, 25% percentile was given, normalized | Weighted by the exposure map | |
| | | Maerl and Furcellaria harvesting | No buffer considered, polygon data converted first to 100 $m^2$ and then to 1 $km^2$ grid cells | - | Calculated amount/area of harvested material, normalized | Not relevant | |
| | | Scallop and blue mussel dredging | No buffer considered, polygon data converted first to 100$m^2$ and then to 1 $km^2$ grid cells | - | Sum of scallop and blue mussel dredged per year, averaged for 2011-2015, normalized | Not relevant | |
| Changes to hydrological conditions (e.g. by constructions impeding water movements) | cumulative | Hydropower dams | a grid cell in the estuary (no extent added) | - | 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 | Extent based on wind farms and cables, but expanded to 1 km because hydrological parameters are widely spreading. | Location of water course modifications | Not relevant | |
| | | Wind farms | 300 m buffer around each turbine with linear decline | See Table 4. | Location of operational wind farms as polygons | Not relevant | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | Oil platforms | 500 m buffer around each turbine with linear decline | See Table 4. | 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 to 100 $m^2$ and then to 1 $km^2$ grid cells | - | Location of cables, Intensity was scaled by the area in the grid cell. | 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 | 1 km buffer with steep decrease around outlet | See Table 3 (decline) . Extent based on Ilus et al. 1986, | 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) | 1 km buffer with steep decrease around outlet | See Table 3 (decline) . Extent based on Karppinen et al. 2011, Karppinen & Vatanen 2013 | Average input of warm water (Celcius) from the nuclear power plant outlets | Not relevant | |
| Input of hazardous substances | temporary | CHASE Assessment tool concentration component: mean contamination ratio per assessment station | Interpolated map from the CHASE station data. | - | Mean contamination ratio of the CHASE assessment tool concentration component | Not relevant | Not relevant |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Introduction of radionuclides | temporary | 10 km buffer with linear decline from discharges of radioactive substances | Gradual buffer around outlet to 10 km distance | Based on Ilus et al. 1986 | 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 | See the next column. | 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 | See the next column. | 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 nutrients | temporary | Interpolated nitrogen and phosphorus concentrations in separate layers | Mean value per grid cell. | - | Total nitrogen and total phosphorus concentrations (annual mean) from 0-10m surface layer. | Not relevant | Not relevant (separate data layers) |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 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:<br>0-10m= 100%<br>10-15 m= 70%<br>15-20 m= 50%<br>20-30 m= 20%<br>30-40 m = 10%<br>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. |
| | | **1 km buffer.** Bathing sites, beaches | point data converted directly to 1 km grid cells | Estimate by TAPAS project of the human disturbance (noise, water sports, visual disturbance) | Location of beaches presented as presence / absence | Not relevant | |
| | | **5 km buffer.** Population density | Coastal population density polygon data converted directly to 1 km grid cells | Estimate of the human disturbance (noise, visual disturbance) | Population density at 100 m distance from the shoreline was selected and 5 km buffer was created where the pressure intensity was presence / absence of the area | rescaled with depth:<br>0-4m= 100%<br>4-7 m= 70%<br>7-10 m= 50%<br>10-20 m= 20%<br>20m < =0% | |
| Extraction of, or mortality/injury to fish | temporary | **0 km.** 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). |
| | | **0 km.** 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. | temporary | **0 km.** Game hunting of seabirds | Varying reporting units, from counties | - | Species summed together, average of killed seabirds of years 2011-2015 per reporting | Not relevant | Normalized values summed together |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| hunting, predator control) | | | to HELCOM subdivisions | | unit, numbers of killed birds / km2 calculated and generalized for the whole reporting unit, normalized | | |
| | | **0 km.** 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 | **0 km.** 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 | **50 km buffer**. 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 |

# Annex 2. The TAPAS expert survey

The TAPAS project developed a detailed questionnaire to be responded by Baltic Sea experts through the HELCOM contact points. This 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 survey covered a matrix of 750 potential pressure- and ecosystem-specific combinations (See tables 1 and 3 in this report). In order to estimate 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 was 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 A.2.1 could be assumed to be relevant for the pressure in question.

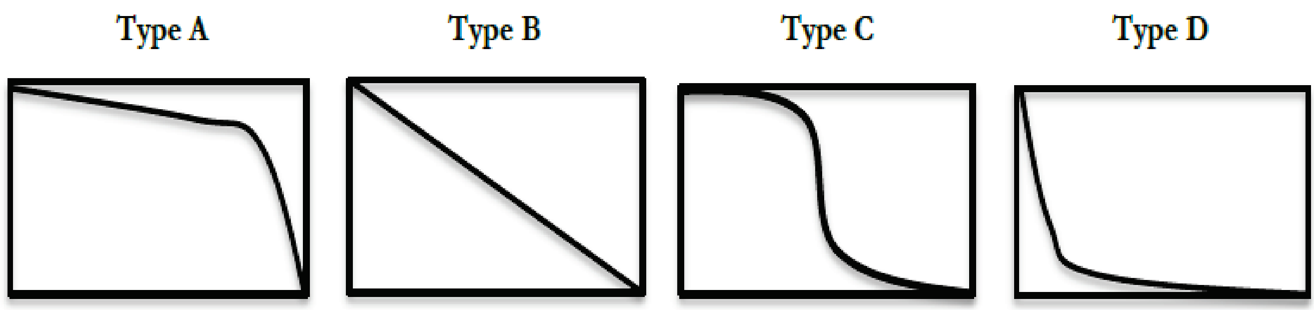


Figure A.2.1. Impact types A, B, C and D. Type A describes a pressure that has a similar impact at most of its distribution range and then rapidly drops, type B describes a pressure that declines monotonously in strength from the source, type C describes a pressure having a somewhat limited decline within 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 are 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 can be retrieved at [http://www.helcom.fi/Documents/TAPAS_survey.xlsm](http://www.helcom.fi/Documents/TAPAS_survey.xlsm). In order to use the survey, users should enable the macros of the file.

# Annex 3. Impact types and distances

Table A.3.1 shows the impact distances and impact types per pressure based on the results from the expert survey. The minimum, maximum and mean distances were first calculated based on all obtained responses at the level of each ecosystem component, and the table shows the corresponding values subsequently calculated across all ecosystem components. The standard deviation shows variability in the mean value among the ecosystem components.

Table A.3.2 shows impact distances by human activities based on the literature survey.

The information was used as background information for processing the pressure layers, as outlined in Annex 1.

Table A.3.1. Impact distances and impact types per pressure, based on the results from the expert survey. The column 'impact type' shows what impact type was indicated in most cases among the respondents. The value is the average % of the replies indicating that pressure type across all ecosystem components (higher values indicate that the type was identified more frequently as the predominating type, as depicted in Figure A.2.1). For pressures marked *, literature information used instead. Pressures marked ** were not finally used in the assessment.

| **Pressure** | **Min (km)** | **Max (km)** | **Mean (km)** | **Standard deviation (km)** | **Impact type** |
|---|---|---|---|---|---|
| 1. Physical loss* | 0.1 | 9.4 | 2.4 | 2.6 | D (58%) |
| 2. Physical disturbance* | 0.8 | 10.6 | 2.5 | 2.3 | D (34%) |
| 3. Changes to hydrological conditions* | 0.5 | 26.8 | 7.2 | 6.3 | A (39%) |
| 4. Inputs of continuous anthropogenic sound | 5.0 | 26.4 | 15.6 | 5.2 | B (31%) |
| 5. Inputs of impulsive anthropogenic sound | 2.5 | 25.7 | 11.8 | 5.2 | N.A. |
| 6. Inputs of other form of energy (electromagnetic and seismic waves) | 0.1 | 10.2 | 4.9 | 3.6 | A (48%) |
| 7. Input of heat | 0.1 | 6.5 | 3.0 | 1.9 | D (33%) |
| 8. Inputs of hazardous substances | 0.5 | 32.9 | 20.2 | 7.5 | D (39%) |
| 9. Inputs of nutrients | 13.7 | 43.0 | 25.7 | 7.4 | B (53%) |
| 10. Introduction of radionuclides | 10.0 | 46.4 | 34.6 | 6.6 | D (40%) |
| 11. Oil slicks and spills | 7.1 | 33.2 | 16.5 | 6.1 | D (38%) |
| 12. Inputs of litter | 6.2 | 34.1 | 15.7 | 6.8 | D (60%) |
| 13. Inputs of organic matter | 9.3 | 36.9 | 20.5 | 7.4 | B (52%) |
| 14. Disturbance of species due to human | 0.0 | 14.0 | 1.9 | 2.7 | C (32%) |
| 15. Extraction of, or mortality/injury to fish | 2.0 | 38.6 | 11.6 | 9.2 | C (30%) |
| 16. Extraction of, or mortality/injury to mammals and seabirds (e.g. hunting, predator control) | 1.0 | 42.5 | 19.7 | 10.5 | B (42%) |
| 17. Introduction of non-indigenous species and translocations | 14.0 | 41.0 | 27.8 | 6.8 | B (47%) |

| | | | | | |
|---|---|---|---|---|---|
| 18. Changes in climatic conditions** | 22.0 | 50.0 | 46.9 | 7.1 | A (28%) |
| 19. Acidification** | 32.0 | 50.0 | 46.1 | 5.3 | A (40%) |

Table A.3.2. Spatial extent of physical disturbance from different human activities. The extents were estimated as the distance from the activity at which the pressure intensity can be considered negligible. Note that the estimates are also affects by hydrographic conditions, and that the estimates given here are usually applicable to exposed or semi-exposed areas. The information is based on results from the BalticBOOST project, and was used as a complement to the expert survey for processing the pressure data layers (Annex 1).

| **Human activity** | **Pressure extent (specification to ecosystem component given in brackets)** | **Literature reference** |
|---|---|---|
| Capital dredging | 4 km (fish), 3 km (benthos), 3 km (vegetation), 3 km (water turbidity) | Lassalle *et al*. 1990, Morton 1996 , Kotta *et al*. 2009, Vatanen *et al*. 2012 |
| Maintenance dredging | 4 km (fish), 3 km (benthos), 3 km (vegetation), 3 km (water turbidity) | Lassalle *et al*. 1990, Boyd *et al*. 2003, Orviku *et al*. 2008, Vatanen *et al*. 2010 |
| Sand extraction | 5 km (water turbidity), 4 km (fish), 3 km (vegetation), 2 km (benthos) | Nichols *et al*. 1990, Boyd *et al*. 2003, Phua *et al*. 2004, Vatanen *et al*. 2012 |
| Disposal of dredged matter | 4 km (fish), 3 km (benthos), 3 km (vegetation), 2 km (water turbidity) | Syväranta *et al*. 2013, Syväranta & Leinikki 2014, Vatanen *et al*. 2014, Syväranta & Leinikki 2015, Vatanen *et al*. 2015 |
| Shipping and ferry traffic | 1 km (fish), 1 km (water turbidity, 30 m in depth), 0.5 km (vegetation), 0.3 km abrasion (substrate change) | Rytkönen et al. 2001, Vahteri & Vuorinen 2001, Soomere *et al*. 2003, Eriksson *et al*. 2004, Sandström *et al*. 2005, Vatanen *et al*. 2010, Syväranta & Vahteri 2013 |
| Boating | 0.5 km (water turbidity, 4 m in depth), | Degerman & Rosenberg 1981, Oulasvirta & Leinikki 2003, Eriksson et al. 2004, Sandström *et al*. 2005 |
| Marinas | 0.5 km (fish), 0.5 km (vegetation) | Eriksson *et al*. 2004, Sandström *et al*. 2005; and the references in 'Dredging' |
| Demersal trawling (siltation) | 0.1 km | |
| Demersal trawling (abrasion) | local | |
| Wind turbines, oil rigs (operational) | 0.1 km | Eastwood *et al*. 2007 |
| Wind turbines, oil rigs (construction) | 300 m (wind turbines), 500 m (oil rigs) | Roth 2004, Eastwood *et al*. 2007, Andersson 2011, van der Wal & Tamis 2014; and the references in 'Dredging' |
| Cable placement | 0.5-1km | Andrulewicz *et al*. 2003, Kogan 2006; and the references in 'Dredging' |

# Annex 4. Evaluation of sensitivity scores

## SENSITIVITY SCORES FROM THE EXPERT SURVEY

### *Results for 'Tolerance'*

With regard to the theme 1 (tolerance), there was a large variation in the number of replies per combination of pressure and ecosystem component. Between 1 and 35 replies were provided to the different combinations (mean number of replies = 12.1, standard deviation= 6.1). Only one response was given to the ecosystem component 'Submarine structures made by leaking gases' (also with respect to themes 2 and 3 below). There was also some variability in the obtained responses, that is, the scores provided by different experts. The standard deviation around the mean for responses to a certain combination of pressure and ecosystem component was on average 0.55, ranging between 0 and 1. Replies with high variability (a standard deviation above 1.0) can be regarded7 as less reliable compared to those with lower standard deviation.

### *Results for 'Recoverability'*

For theme 2 (recoverability), there was also large variation in the number of replies for each combination of pressure and ecosystem component (between 1 and 35 replies, mean number of replies = 11.8, standard deviation = 6.1). The variability in scores among obtained responses was higher than for tolerance. The standard deviation around the mean for responses to a certain combination of pressure and ecosystem component was on average 0.62, ranging between 0 and 1.41.

### *Results for 'Sensitivity'*

For theme 3 (sensitivity) the number of replies for each combination of pressure and ecosystem component ranged between 1 and 35, with a mean value of 11.4 responses per combination (standard deviation = 5.7). The variability in scores among responses, as measured by the standard devaluation from the mean, was on average 0.62, ranging between 0 and 1.41.

### *Correlation among results*

The correlation between the sensitivity scores and the other two themes (tolerance, recoverability) was evaluated as part of the quality assurance. The highest correlation was observed between 'sensitivity- and 'tolerance' (Figure A.4.1). According to the definition of the factor 'sensitivity' in the expert survey, it should include the aspects of both of the other two factors.

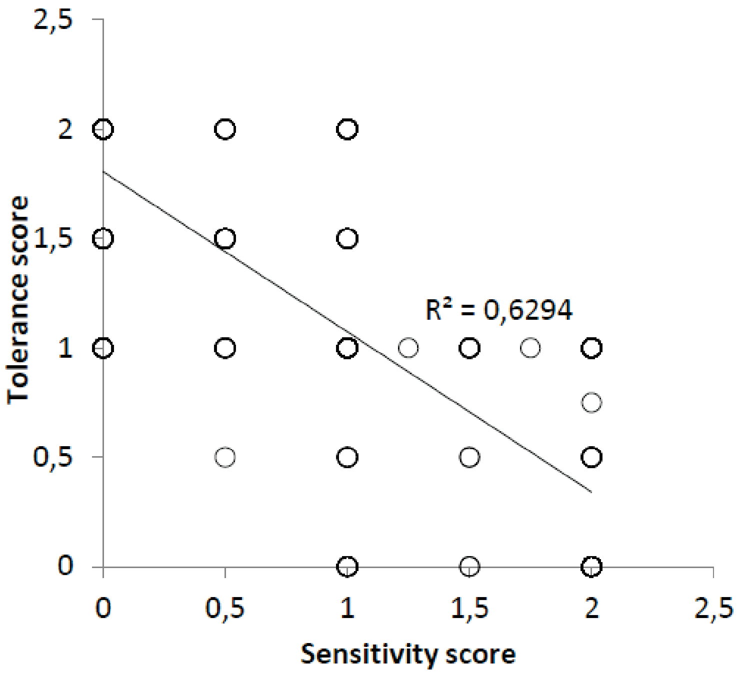


Figure A.4.1. Correlation between the mean scores for 'tolerance' and 'sensitivity' among all responses for combinations of pressures and ecosystem component. The obtained correlation value $R^2$ was 0.63, which is higher than for the correlations between scores for 'sensitivity' and 'recoverability' ($R^2$=0.20).

# LITERATURE INFORMATION ON BENTHIC HABITATS

The literature to support the setting of sensitivity scores for benthic habitats with respect to the pressures 'Physical disturbance' and 'Changes in Hydrological conditions' shown given in Tables 6 and 7 of this report. Literature to support the assessment of other pressures impacting on benthic habitats is listed in table A.4.1.

Table A.4.1. Sensitivity of benthic habitats to other pressure types based on the literature review.

| | **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 (Bonsdorff *et al.* 1986).
(2) Recovery time of zoobenthos is 8- >10 years (Bonsdorff *et al.* 1986).
(3) Recovery time of zoobenthos is ca 5 years (Bonsdorff *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)

# ADDITIONAL LITERATURE INFORMATION TO SUPPORT THE EVALUATION OF SENSITIVITY SCORES

The sensitivity of species groups to other pressure types based on the information in the literature review is presented in table A.4.2.

Table A.4.2. Sensitivity of species groups to other pressure types based on the information in the literature review.

| | **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, 2) Andersson (2011); (3) Bergström *et al.* 2014 ; (4) Andrulewicz *et al.* 2003; (5) Gill 2005; (6) Wilhelmsson *et al.* (2010) | | | | |

# COMPARISON OF EXPERT SURVEY RESULTS AND LITERATURE REVIEW

## Physical loss

The literature review suggested that all the sensitivity scores for the 'physical loss' pressure be set to 'High' for benthic habitats. The expert survey gave that the mean score for benthic habitats is 1.83 of the maximum 2.0, and that the experts considered benthic habitats to be highly sensitive to physical loss. For the two pelagic habitats, the expert survey gave the scores 0.4 and 0.9 and for mammals, seabirds and pelagic fish the mean score is 0.86 (range 0.5-1.2). No literature evidence was available to contradict this. Spawning areas of coastal fish (roach, pike and pikeperch, spawning among benthic vegetation) received scores 1.3-1.4 in the expert survey which is against the findings of the literature survey where benthic vegetation was shown to be sensitive to physical loss. The expert survey was followed after increasing the scores by 20%.

## Physical disturbance on seabed

The pressure 'physical disturbance on seabed' was estimated by the literature review as highly impacting and the sensitivity scores were 'high' in almost all cases, but the range of habitats considered in the literature study was not as wide as in the expert survey. 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 (the mean is 1.6 (range 1.5-1.7) if 'submarine structures made by leaking gases' is omitted). The maximum score is 2.0. The results shows that the benthic habitats are highly sensitive to this pressure. The observed variability indicated that the experts considered that the more biological elements are included in the habitat classification, the more sensitive is the habitat. For example, the habitat-forming species were considered more sensitive than the broad-scale habitats or Natura 2000 habitats. The sensitivity of pelagic habitats (surface and deep) to physical disturbance was scored as 1.0 and 0.7, respectively, indicating moderate 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 'moderate' (i.e. score 1.0). The 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. The literature review supported the expert survey and the results from the expert survey were used.

## Changes in hydrological conditions

Changes in hydrological conditions were not estimated to be as serious as the other two physical pressures according to the expert survey. The broad-scale habitats had sensitivity scores ranging between 0.9 and 1.4 (mean 1.17), indicating moderate impacts, which is partly in line with the literature review, where deeper habitats were estimated as 'low sensitivity' and infralittoral habitats as 'moderate'. 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). The expert survey results were used.

### Input of continuous sound

Sensitivity to input of continuous sound was estimated by the expert survey as highest to the marine mammals (mean 1.52), 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. The moderate sensitivity of harbor porpoise was likely an underestimation in the literature review. The expert survey results were used.

### Input of impulsive sound

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 moderate-high sensitivity was suggested for all the ecosystem components. As the literature was not referring to real measurements but to assumptions, the expert survey results were used.

### Electromagnetism

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 results were used.

### Input of heat

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 ‘moderate’. The expert survey results were used.

### Input of hazardous substances

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. The results seemed to be in contrast with the expert results which considered benthic habitats to be moderately sensitive. The difference may be due to high variability in substances and pollution levels; highly contaminated sediments may cause acute mortality whereas accumulative effects are more of a problem for long-living predators. There was also some uncertainty among experts about the effects on habitats (and associated species). The expert survey results were used as no specific review was made for the contamination.

### Input of nutrients (nitrogen and phosphorous)

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 the scarce literature information, benthic broad-scale habitats were mostly scored as 'moderately sensitive', which is in line with the expert survey. Knowing that there is high expertise in eutrophication impacts in the Baltic Sea science community. The expert survey results were used.

### Input of radionuclides

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 one reference, which indicated moderate sensitivity for broad-scale habitats. The expert survey results were used.

### Oil slicks and spills

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 and the expert survey results were used.

### Input of litter

The expert survey showed low sensitivity of most of the ecosystem components. Exceptions were seabirds and marine mammals, which scored between 0.9-1.2, while other ecosystem components scored between 0.1 and 0.8 (mean 0.42). No literature information was available through the review and the expert survey results were used.

### Input of organic matter

Sensitivity to input of organic matter was relatively clear 'moderate' 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. This pressure layer was not included in the Baltic Sea Impact Index.

### Disturbance to species

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 and the expert survey results were used.

### Extraction and injury to fish

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 and the expert survey results were used.

### Hunting of seals and seabirds

Hunting of seals and seabirds (including predator control) was estimated to score 1.9 in average (range 1.6-2.0) for seals and 1.65 in average for seabirds (1.6-1.7). 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. As this pressure describes hunting, bycatch of harbor porpoise was not included in this pressure but in 'Extraction and injury to fish'.

### Introduction of non-indigenous species and translocations of native species

Sensitivity of ecosystem components to introduction of non-indigenous species and translocations of native species was generally scored in the survey as 'moderate' (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 seems 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. As literature has shown that the common invasive non-indigenous species, such as round goby and mud crab have strong impacts to habitats formed by blue mussels and vegetation (Kuhns & Berg 1999, Lederer *et al*. 2008), the sensitivity scores of benthic habitat-forming species (ranging from 0.7 to 0.9) in the experts survey were increased by 50% (to ranging from 1.0 to 1.4).

## Changes in climatic conditions

Sensitivity of the Baltic Sea habitats and species to changes in climatic conditions was estimated in the expert survey as 'moderate' (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.

## Acidification

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, boreal Baltic islets), but this pattern was not consistent. No literature information was available through the review. This pressure layer was not included in the Baltic Sea Impact Index.