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Background

The HELCOM Second Holistic Assessment will include a chapter on 'Pressures and human activities acting on the environment' that will comprise an assessment of the impact on specific geographical areas and ecosystem components (Outcome of HOLAS II 6-2016, Annex 2). The cumulative impacts on habitats and species will be assessed by the Baltic Sea Impact Index (BSII).

The HELCOM TAPAS project has the objective to further develop the BSII method which was originally applied in the HELCOM Initial Holistic Assessment in 2010. The project component of TAPAS that develops the BSII will end by December 2016. The project particularly focuses on improving spatial and temporal aspects of the input data as well as the reliability of estimates for habitat and species sensitivity to anthropogenic pressures.

Guidance to the tool development has been provided through expertise from the Contracting Parties through two HELCOM TAPAS workshops (HELCOM TAPAS Pressure Index WS 1-2016, HELCOM TAPAS Pressure Index WS 2-2016) and through HOLAS II project meetings (HOLAS II 4-2015, HOLAS II 5-2016, HOLAS II 6-2016.

Information on how recommendations from the second TAPAS workshop and HOLAS II 6-2016 has been taken into account is included in Annex 1.

This document presents the methods to develop the spatial input data and how the spatial cumulative impact assessment is proposed to be calculated.

Action requested

The Meeting is invited to:

- agree on the method to evaluate the spatial cumulative impact assessment and endorse its use in the HOLAS II project,
- agree on the method to develop the input data to the cumulative impact assessment and endorse its use in the HOLAS II project,
- take note that there are three complementary outputs of the index value that will still be tested, and agree to endorse the final output format for the BSII intersessionally.

Method to calculate the Baltic Sea cumulative impact index (BSII)

Contents

1. Introduction

The Baltic Sea Impact index (BSII) was first applied in the Initial HELCOM Holistic Assessment of Ecosystem Health (HELCOM 2010a)[1], building on concepts described by Halpern et al. (2008)[2]. The methods that were applied to the input data are described in HELCOM (2010b)[3] and Korpinen et al. (2012)[4]. The concepts were subsequently developed further for the eastern parts of the North Sea by the HARMONY project [5], which has developed a HARMONY Pressure & Impact Mapper software (Stock 2016)[6]. The same methodology has also been used in the Mediterranean and the Black Sea[7].

The Baltic Sea Impact Index (BSII) is based on georeferenced data sets of human activities, pressures and ecosystem components, and on sensitivity estimates of ecosystem components (so-called sensitivity scores)

[1] HELCOM (2010) Ecosystem Health of the Baltic Sea: HELCOM Initial Holistic Assessment. Baltic Sea Environment Proceedings 122. Available at: http://www.helcom.fi/stc/files/Publications/Proceedings/bsep122.pdf;
[2] Halpern, B. S., S. Walbridge, K. A. Selkoe, C. V. Kappel, F. Micheli, C. D'Agrosa, J. F. Bruno, K. S. Casey, C. Ebert, H. E. Fox, R. Fujita, D. Heinemann, H. S. Lenihan, E. M. P. Madin, M. T. Perry, E. R. Selig, M. Spalding, R. Steneck, and R. Watson. 2008. A Global Map of Human Impact on Marine Ecosystems. Science 319:948-952.
[3] HELCOM, 2010b. Towards a tool for quantifying anthropogenic pressures and potential impacts on the Baltic Sea marine environment: A background document on the method, data and testing of the Baltic Sea Pressure and Impact Indices. Balt. Sea Environ. Proc. No. 122
[4] Korpinen, S., Meski, L., Andersen, J.H. and Laamanen, M. (2012). Human pressures and their potential impact on the Baltic Sea ecosystem. Ecological Indicators 15:105-114.
[5] Andersen, J.H. and Stock, A. (eds.), Heinänen, S., Mannerla, M. and Vinther, M. (2013). Human uses, pressures and impacts in the eastern North Sea. Aarhus University, DCE – Danish Centre for Environment and Energy. Technical Report from DCE – Danish Centre for Environment and Energy No. 18. 134 pp.
[6] Stock, A. (2016). Open Source Software for Mapping Human Impacts on Marine Ecosystems with an Additive Model. Journal of Open Research Software, 4: e21, DOI: http://dx.doi.org/10.5334/jors.88
[7] Micheli, F., B. S. Halpern, S. Walbridge, S. Ciriaco, F. Ferretti, S. Fraschetti, R. Lewison, L. Nykjaer, and A. A. Rosenberg. 2013. Cumulative Human Impacts on Mediterranean and Black Sea Marine Ecosystems: Assessing Current Pressures and Opportunities. PLoS ONE 8:e79889

that combine the pressure and ecosystem component layers. The scores estimate the potential impact of each assessed pressure on specific ecosystem components.

HOLAS II 3-2015 agreed that the indices and key concepts used in the Initial HELCOM Holistic Assessment of Ecosystem Health should also be used for assessing cumulative pressures and impacts from multiple human activities in the 2nd HELCOM Holistic Assessment but that they should be developed further.

2. Main features of the Baltic Sea Impact Index (BSII)

Cumulative impacts are calculated for each assessment unit (1 km^2 grid cells) by summing all impacts occurring in the unit for each ecosystem component (Figure 1). The method allows several ecosystem component layers per grid cell and, in such a case, there are three options to calculate the index: a) as a sum (Figure 1A), b) as an average (Figure 1B), or c) select the ecosystem component receiving the highest cumulative impacts.

A

$$I_C = \sum_{i=1}^{n} \sum_{j=1}^{m} D_i * E_j * \mu_{i,j}$$

B

$$I_C = \sum_{j=1}^{n} \frac{1}{m} \sum_{i=1}^{m} D_i \times E_j \times \mu_{i,j}$$

Figure 1. Calculation of cumulative impacts by (A) summing up all ecosystem component layers in a grid cell or (B) taking the average of cumulative impacts across the ecosystem component layers.

For use in the BSII method, 39 ecosystem component layers have been developed (Document 4J-19) and their use was supported by the HELCOM HOLAS II 6-2016. The meeting however discussed the obvious gaps in the habitat and species distribution maps, especially in regard to the Natura 2000 habitats, and hence that it may be more relevant to use the averaging method or the 'highest impacts' method rather than the sum. While the 'summing method' was used in HOLAS I, the 'averaging method' has been used more recently in many scientific papers and it can deal with the incomplete ecosystem component data. The 'highest cumulative impact' method might be still more appropriate to show risk areas. The differences of these methods remains to be tested in the HELCOM TAPAS project and results can be expected by the end of November 2016.

18 aggregated pressure layers will be used in the BSII, consisting of 48 more specific data layers of pressures and human activities (being proxies for pressures) (Document 4J-19). The meeting of HOLAS II 4-2015 recommended that the pressure input data in BSII should be in balance between different types of anthropogenic pressures and therefore data layers should be aggregated. These 18 aggregated pressure layers follow the indicative list given in the Table 2a of the proposed revision of the Marine Strategy Framework Direction (MSFD) Annex III. The meeting HOLAS II 4-2015, however, proposed some modifications to the list to make it more applicable to the Baltic Sea conditions. For instance, pressures not taking place in the region were omitted and some pressures were divided if they were considered important for the region. In addition to aggregated pressure layers, three climate change variables are to be taken into account.

The method allows also calculation of **cumulative pressures** which are calculated without including ecosystem data into the method. The method sums the pressure intensities per unit. This was presented in the HELCOM Initial Holistic Assessment in the Baltic Sea but no recommendation has been made whether it would be needed in the 2nd HELCOM Holistic Assessment.

The cumulative impacts can be calculated by readily available software (Stock 2016), and the description of the calculation process is given below.

3. New developments of the index

3.1 Impact chains from activities to pressures and impacts

The BSII method will build on a linkage framework which will allow the impact assessment to be back-tracked to the pressures, human activities and the activity sectors. Linkage frameworks are compiled by the HELCOM TAPAS[8] and the BalticBOOST[9] projects on the basis of the FP7 ODEMM project[10], OSPAR[11], JNCC[12] and INPN[13]. An interim HELCOM linkage framework is available at the HELCOM web site and a finalized version for the HOLAS II purposes will be ready by the end of November 2016. The linkages are referred to as impact chains[14]. In the HOLAS II assessment of activities, pressures and impacts, these chains allow a flexibility to perform assessments for different purposes (e.g. an assessment of pressures stemming from a selected activity or vice versa). This functionality was not present in the Initial Holistic Assessment.

3.2 Development of the spatial extent of pressures

Many of the data layers used show the location of human activities but they do not, by that, give the spatial distribution of pressures stemming from that activity. To represent the resulting pressures in a more realistic way, the TAPAS project, supported by the BalticBOOST project (WP3.1) has made a literature study of the spatial extents of pressures from different sources and these are applied in the preparation of the pressure data layers. Interim spatial extents are given in Annex 2. The estimate of spatial extent will be further supported by the TAPAS expert survey (see section 4). In addition, for pressures that diminish at increasing distances from their source, the spatial representation of the pressures needs to incorporate the correct form of this decline. This gradient will be used to reduce pressure intensity values away from the source in the specific pressure data layers (column C in Annex 2) and the resulting pressure values will be combined in the aggregated pressure data layers (column A in Annex 2).

3.3 Adding the effects of seabed exposure and water depth

The effects of water depth or seabed exposure on pressure intensity have not been included in previous assessments of cumulative impacts, even though they influence the pressure intensity in many cases. This does not apply to all pressure types, but has significant consequences on the extent on some pressures by avoiding over-estimation of their impacts in deep or exposed areas. The approach was recently tested for the Finnish Archipelago Sea[15]. The pressures affected by water depth are mainly resuspension (physical disturbance) caused by shipping and biological disturbance caused by human activities taking place on the surface. The spatial gradients of pressures studied in the BalticBOOST and TAPAS projects (see previous section) are applied to these two pressure layers by down-weighting the pressure values in deeper waters. Annex 2 gives such values, for instance, for the physical disturbance caused by shipping and boating.

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[8] The HELCOM coordinated EU co-financed project: Development of HELCOM tools and approaches for the Second Holistic Assessment of the Ecosystem Health of the Baltic Sea
[9] 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
[10] http://odemm.com/content/linkage-framework
[11] http://qsr2010.ospar.org/media/assessments/p00443_BA6_assessment-final.pdf
[12] http://jncc.defra.gov.uk/pdf/Final_HBDSEG_P-A_Matrix_Paper_28b_Website_edit%5b1%5d.pdf
[13] https://inpn.mnhn.fr/programme/sensibilite-ecologique?lg=en
[14] Knights, A., Koss, R.S. and Robinson, L. (2013). Identifying common pressure pathways from a complex network of human activities to support ecosystem-based management. Ecological Applications 23: 755-765.
[15] Sahla, M. 2015, Sensitivity and the gaps of knowledge for cumulative human pressure modelling in the Archipelago Sea. MSc Thesis, 95 p., 3 app. University of Turku, Faculty of Mathematics and Natural Sciences, Department of Geography and Geology. [Summary in English].

The pressures affected by the seabed exposure are the input of organic matter and physical disturbance (sedimentation). The Baltic-wide map on seabed exposure[16] will be used to down-weight the pressure values in shallow exposed areas and overweight them in sheltered areas for these two pressure types.

3.4 Proposal for temporal aspects in pressure data

Temporal characteristics of the pressures are taken into account in the data processing, by designing the spatial data sets so that they more accurately represent more lasting or temporary pressures. The simplest approach is to consider if there is additivity of the pressures over time; for pressures that last long (e.g. loss of a habitat) assessment values will be the cumulative value for all years during the entire assessment period (2011-2016), whereas for more temporary pressures assessment values are annual averages over the assessment period. This is being implemented for the pressure data sets prepared by the HELCOM Secretariat. The chosen method is listed in Annex 2 of this document.

3.5 Solutions for estimating pressure magnitudes

When aggregating several activities, which are measured in different metrics, to a single pressure there is a problem of unbalance in the magnitude of the pressures originating from different activities. This can cause overestimations of pressures from some activities. This problem could be avoided if sensitivities could be given to more specific pressures arising from human activities (such as physical disturbance from wind farm construction). Since such specific sensitivity scores have not been collected in HOLAS II, the BalticBOOST and TAPAS projects have developed together a method to solve this problem. The BalticBOOST literature review has catalogued pressure and impact magnitudes from different human activities and then synthesized these into a ranking (Table 1; see also Section 4 for more information of the catalogue). The ranking has been categorized (0- <20%, 20- <40%, 40- <60%, 60- <80% and 80- 100%) and the categories indicate the relative differences of activities causing the physical disturbance pressure. These categories can be used as downweighting factors (0.2, 0.4, 0.6, 0.8 and 1.0) to the specific pressure data layers before they are aggregated (see Annex 2 for the list of aggregated pressures and the more specific pressure data layers). Table 1 shows an interim result from these categories for the physical disturbance. Final results will be produced according to the project timetable by the end of November 2016.

Table 1. Ranking and categorization of physical disturbance pressures from different human activities. All the rankings are temporary and will be finalized with the BalticBOOST WP 3 work by the end of November 2016.

Rank	**Activity causing physical disturbance**	**Category**	**Weight**
High pressures and impacts	Bottom-trawling, Demersal seining (Danish and Scottish), Demersal long-lining, Scallop and blue mussel dredging, Maintenance and capital dredging (incl. harbours), Sand extraction and Sediment disposal	80-100%	1
Moderate to high	Construction of water course modification and Coastal defence and flood protection, Finfish mariculture, Shellfish mariculture	60- <80%	0.8
Moderate	Wind turbine construction, Contaminated sediments, Shipping, Marinas	40- <60%	0.6
Low to moderate	Boating, Pipeline placement, Maerl and furcellaria harvesting	20- <40%	0.4
Low	Cable placement	0- <20%	0.2
No		0	0

[16] Bekkby, T., Isachsen, P.E., Isæus, M., Bakkestuen, V. 2008. GIS modelling of wave exposure at the seabed: A depth-attenuated wave exposure model. Marine Geodesy 31(2): 117-127.

4. Development of sensitivity scores for habitats and species

4.1 Literature review

Sensitivities of habitats and species (i.e. ecosystem components) are estimated through a literature review carried out by the BalticBOOST WP3 (only for benthic habitats) and an expert survey carried out by the TAPAS Theme 1 (all ecosystem components). The literature review is still on-going and the final sensitivity scores are not ready, but the method deriving them is described below.

The BalticBOOST WP 3.1 has collected a catalogue of circa 120 studies with >380 hits for different impacts on benthic habitats. The catalogue is still developing but will be made available later in 2016. The catalogue includes information of the type of activity, pressure it is causing, intensity of the pressure, lasting of the pressure, target of the impact, type of impact, magnitude of the impact, spatial extent of the impact, recovery from the impact, region of the study, type of study and reference. The catalogue has been synthesized into a table summarizing the level of activity and magnitude of pressure and impact on different benthic habitats and species. The synthesis also summarizes recoverability from the pressure and the spatial extents.

Based on the synthesis, the project is estimating sensitivities of benthic habitats and species to the pressures affecting them. At the moment, there are still some needs to fill gaps in the catalogue but the method to derive the sensitivity scores has been developed to be comparable with the outcome from the TAPAS expert survey (Table 2). The magnitude of impact and recoverability after cessation of a pressure are categorized. The impact categories being: no impact, low impact, moderate impact and high impact; and the recoverability categories being: slow recoverability, moderate recoverability, high recoverability, immediate recoverability. The sensitivity of the ecosystem component is estimated on the basis of Table 2.

The literature review will produce sensitivity scores for predominant pressures in benthic habitats and species (as listed in document 4J-19).

Table 2. Impact and recoverability categories of the literature study and the resulting sensitivity scores.

	immediate recoverability	high recoverability	moderate recoverability	slow recoverability
no impact	very low sensitivity	low sensitivity	low sensitivity	low sensitivity
low impact	low sensitivity	low sensitivity	moderate sensitivity	moderate sensitivity
moderate impact	low sensitivity	moderate sensitivity	moderate sensitivity	high sensitivity
high impact	moderate sensitivity	moderate sensitivity	high sensitivity	high sensitivity

4.2 Expert survey

The expert survey to derive sensitivity scores for the BSII pressures and ecosystem components is on-going and responses from Contracting Parties are expected during October. The HOLAS II 6-2016 expressed its worry for the low response rate reported to the meeting and emphasized that the replies can be given also by more generalists as the confidence of the replies must always be given in the survey. To increase the response the survey was submitted to contacts of HELCOM expert groups, project and network on 11 October 2016 and also made available on the HELCOM website.

The survey asks categorical estimates for tolerance, recoverability and sensitivity of ecosystem components to anthropogenic pressures. While the sensitivity can be calculated on the basis of tolerance and recoverability (see above), the sensitivity was asked separately in order to receive clearer responses. Additionally, the survey asks spatial extents of the impacts and the attenuation gradient from the pressure source. In addition to the confidence score of each of the replies, respondents can also state whether the reply applies to the entire Baltic Sea or only parts of it. General comments can be given to each reply.

The Second HELCOM TAPAS Workshop on Pressure and Impact Index, 6-7 September 2016 recommended a method to combine the responses of the expert survey. In brief, the method is following: a median value will be taken from the replies to tolerance, recoverability and sensitivity; averages will be taken of the spatial extents and attenuation gradients; averages will be taken from confidence values.

In order to get a single set of sensitivity scores, the literature-based and survey-based values will be combined. This will follow the method as supported by the second HELCOM TAPAS workshop:

- if both approaches give a similar sensitivity, then that becomes the sensitivity score;
- if the sensitivities differ, then the result with higher confidence and less variability is used;
- if none of the above applies but there is more literature evidence, then the literature information is used.
- if there is no literature information, expert survey results are used.

Similar approach is used for spatial extents and gradients.

If the low response rate to the expert survey remains, the HOLAS II should also consider the previously collected sensitivity scores in the Baltic Sea. The methodologies of HOLAS I and HOLAS II are sufficiently similar to enable comparison and potential use of the HOLAS I sensitivity scores.

5. Step-wise description of the method for application in HOLAS II

This section gives a practical description of the steps needed to make the cumulative impact assessment for the Baltic Sea.

1. **Definition of the assessment area**: prepare a GIS file in vector format of the area where the assessment will be made. The BSII will use the HELCOM Convention Area.
2. **Listing and defining human activities and consequent pressures in the Baltic Sea**: list all human activities and their pressures in the assessment area and organize those according to the pressure list and the human activity list e.g. according to the proposed revised MSFD Annex III. Link the pressures and human activities to each other (i.e. which activity is causing or contributing to which pressure). This is called as the Linkage framework.
3. **Listing and defining ecosystem components in the Baltic Sea**: Identify habitats, functional habitats, keystone species or functional groups, which are ecologically most important for the assessment area. The definitions need to be broad enough to capture Baltic-wide features. In the BSII, the following will be used: 1) for benthic habitats, the EMODnet broad-scale habitats and Natura 2000 habitats, 2) habitat-building species, 3) for pelagic habitats, the productive (photic) surface layer and the layer beneath, 4) for mammal, bird and fish species, characteristic species for the Baltic Sea will be used as well as the habitats they use.
4. **Decisions on time scales**: decide the assessment period (→ for BSII data collection period: 2011-2016)
5. **Collecting the spatial data for Baltic sea**: based on the lists in steps 2 and 3, collect spatial data. The data must cover the entire assessment area. Sometimes the pressure data may need to be estimated from human activity data. The pressures are quantified and the data should be in the same metric, if possible. If not, then alternative methods need to be used to aggregate the data layers to the pressure layers (see the method description in Section 3.5). The ecosystem data can be either on the presence/absence scale (especially for habitats) or quantified (especially for species).
6. **Preparation of the GIS files**: make the GIS layers for the pressures and the ecosystem components. In case of human activity data consider especially how widely a pressure can spread from the source (i.e. the location of the activity). This is usually the same extent as how widely the impacts occur. Note that this extent differs among the sources. For instance, a plume of waterborne silt input depends on the water outflow from a river or a point source. Note that some attenuation of the pressure will happen and its form should be considered (linear, logarithmic, etc.). Default values in BSII for the spatial extents will be derived from the HELCOM TAPAS project (expert survey) and the

BalticBOOST project (literature review). Exposure of the area will be included to selected pressures to weight down their effects on exposed areas. Also water depth will be included on the basis of bathymetry data and this will weight down selected pressures as identified in the HELCOM TAPAS and BalticBOOST projects.

7. **Aggregation of pressure data layers**: in the BSII the pressure data will be aggregated according to the MSFD Annex III pressure list, as modified by HOLAS II 3-2015 and 4-2015. The aggregation is straightforward if the pressures are in the same metric. If the metrics are different, then alternative aggregation methods will be used (see Section 3.5).
8. **Definition of the assessment unit**: based on the spatial resolution of the input data, define the size and shape of the assessment units. In the BSII, the assessment unit will be a 1 km × 1 km square. The unit size depends on the input data: a coarse input data to a detailed grid may give an over-positive message, while a detailed input data will be masked by too coarse assessment units.
9. **Estimation of the habitat and species sensitivity**: in the BSII sensitivity against pressures will be estimated on the basis of literature review and expert judgment (see Section 4). The sensitivity estimates are based on tolerance against the pressure and recovery from the pressure. The two approaches will be combined by using the following decision process:
    a. if both approaches give a similar sensitivity, then that becomes the sensitivity score;
    b. if the sensitivities differ, then the result with higher confidence and less variability is used;
    c. if none of the above applies but there is more literature evidence, then the literature information is used.
    d. if there is no literature information, expert survey results are used.
10. **Estimation of confidence**: Uncertainty assigned to each input data layer will be used to calculate the confidence of the assessment result: (1) confidence in the pressure data layers, (2) confidence in the ecosystem component layers, and (3) confidence in sensitivity scores. Confidence is decreased by spatial coarseness of the data or by gaps in data coverage. Confidence of the sensitivity scores will be assessed on the basis of: (1) geographical correspondence between the literature study and the target area for the assessment, (2) ecological relevance (is the study performed in an ecologically realistic way), (3) number of available studies, and (4) agreement between different studies (are there several studies available and do they show the same result).
11. **Calculating the index**: the BSII is run according to the three alternative methods as described in Section 2 by using the EcoImpactMapper software (freely available, Stock 2016). Alternatively, the BSII can be calculated by the ArcMap Raster Calculator where pressure – ecosystem component combinations are multiplied by the sensitivity score and then each layer is summed up.
12. **Outcomes of the index:** the index results are usually presented in cartographic form but also various graphs can be produced. In addition, the index can be calculated for separate activities, pressures or ecosystem components.
13. **Validation:** results of the cumulative impacts and pressures are compared with other assessment results in the Baltic sea, such as thematic assessments of biodiversity, eutrophication and contaminants.

Annex 1. Information how recommendations from the second TAPAS workshop and HOLAS II 6-2016 have been taken into account in the BSII method development.

The recommendations are listed in the order of the outcome of the second HELCOM TAPAS workshop and the additional recommendations from the HOLAS II 6/2016 are associated to those numbered paragraphs.

Preparations of the spatial input data

Recommendation 24. For aggregating spatial data sets with **the same metric**, aggregation by addition is generally preferred.

In the method this is followed for the following pressures: Physical loss (metric is km^2), Extraction of fish (metric is tons), Changes to hydrological conditions, Input of heat, Input of litter, Hunting of seals (metric is individuals) and Hunting of seabirds (metric is individuals).

Recommendation 25. For aggregating spatial data sets based on **different metrics** the proposal from the TAPAS project to apply weights prior to aggregation was supported.

This applies to the pressures physical disturbance and biological disturbance and contaminants. The physical disturbance aggregation follows the method proposed in Section 3.5. The biological disturbance will be aggregated likewise. The contaminants will be aggregated by using the CHASE results for contaminants concentrations as advised by the HOLAS II 6-2016.

Recommendation 27. The Workshop supported the proposal to apply **buffer zones and gradients** to data sets on human activities where this is motivated (Annex 2). The buffer should be applied in order to refine the pressure layers in cases where these are derived from maps of human activities. If direct spatial information on the concerned pressure is available, this will be used instead.

The method will follow this: (1) information from the BalticBOOST literature review (synthesis under preparation) and (2) from the TAPAS expert survey (on-going). For the testing of the tool, interim values have been used.

Recommendation 28. The workshop questioned the proposal to use satellite information to represent the **spatial distribution of nutrient loading**. It was proposed that for nutrients a combined approach could be tested so that satellites are used in order to see the direction of the plumes and then this will be combined with measurements in the sea in order to estimate the intensity. **Concentrations in offshore areas** should be used to estimate the distribution of the nutrient pressure.

The HOLAS II 6-2016 supported the project view that the method for spatial nutrient pressure could use of concentration of nutrents in water but adviced to use the same data as for the eutrophication indicator on nutrients.

Recommendation 29. The workshop did not support to weight down the intensity of nutrient and marine litter **due to wave exposure** since exposure cannot be expected to generally cause a dilution of nutrients or marine litter. For other pressures (such as suspended organic matter or silt), accounting for wave exposure could potentially be relevant, provided that the relationship can be substantiated by literature.

The method will weight down only inputs of organic matter and physical disturbance causing siltation/sedimentation, because these substances are washed away from exposed areas.

Recommendation 30. It was concluded that corrections for **water depths** should only be considered with respect to pressures that act on the seabed.

The method will weight down resuspension by shipping (physical disturbance) and human activities causing biological disturbance on seabed.

Recommendation 31. For estimating fishing pressures, aggregating fish catches across fish species may not be relevant. For estimating effects on mammals and seabirds, spatial data sets for pressure factors affecting mammals and seabirds, respectively, should not be aggregated. When assessing the impacts, it should be noted that the relative impact of a pressure may differ between geographic areas.

The method will not aggregate data sets for hunting of birds and mammals into one data layers. The geographical differences will be taken care by the sensitivity scores of specific areas.

Sensitivity of habitats and species

Recommendations 37-41: These recommendations deal with the aspects how to combine the replies to the expert surveys. The recommendations ask for median values for combining sensitivity, tolerance and recoverability scores and average values for the impact type curves.

The method will follow this advice.

Recommendation 44. The workshop supported using the **LiACAT tool** as far as possible in HOLAS II.

Recommendation 45. The TAPAS project will interact with the developers of the LiACAT tool

TAPAS project will upload the survey results to the LiACAT. The LiACAT can visualize linkages and their strength, whereas quantitative synthesis will be available only later in the autumn.

Recommendation 46. The workshop generally supported that the sensitivity scores of the BSII in HOLAS II will build on a combination of literature information and results from the expert survey, using the following decision process:

- if both approaches give a similar sensitivity, then that becomes the sensitivity score;
- if the sensitivities differ, then the result with higher confidence and less variability is used;
- if none of the above applies but there is more literature evidence, then the literature information is used.
- if there is no literature information, expert survey results are used.

The method will follow this recommendation (see section 4).

Confidence

Recommendation 2. If possible, to display uncertainty in the overall assessment results, not only with respect to the data quality aspects.

The method will estimate confidence in three ways: (1) confidence in the pressure data layers, (2) confidence in the ecosystem component layers, (3) confidence in sensitivity scores.

Recommendation 47. Confidence should be assessed systematically also when results are based on literature studies, and that the following criteria should be included:

- geographical correspondence between the literature study and the target area for the assessment
- ecological relevance (is the study performed in an ecologically realistic way)
- number of available studies
- agreement between different studies (are there several studies available and do they show the same result).

The method will follow this recommendation.

Annex 2 Consideration of spatial and temporal aspects of the data layers of anthropogenic pressures to be used in the Baltic Sea Impact Index.

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent[17]	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Physical loss (permanent effects on the seabed)	Cumulative (summed over the period)	Land claim	Area of polygon or 50 m buffer for points, 30m buffer for lines	Calculate area lost (polygon)	Not relevant	Activities are combined andpotentially overlapping areas are removed. Combined layer is intersected with 1 km grid to calculate % of area lost within a cell.
		Water course modification	50 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Coastal defence and flood protection	50 m buffer for lines, 100 m buffer for points	Calculate buffer to indicate lost area	Not relevant	
		Extraction of sand and gravel	area of polygon	Calculate area lost (polygon)	Not relevant	
		Oil platforms	25 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Pipelines	15 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Wind farms	30 m buffer around each turbine	Calculate area lost (polygon)	Not relevant	
		Cables	1.5 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Harbours	polygon with 200 m buffer	Calculate area lost (polygon)	Not relevant	
		Marinas and leisure harbours	point with 200 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Bridges	2 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Bathing sites, beaches	300 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Oil terminals, refineries	point with 200 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Finfish mariculture	150 m buffer	Calculate buffer to indicate lost area	Not relevant	
		Shellfish mariculture	area of polygon	Calculate buffer to indicate lost area	Not relevant	
Physical disturbance or damage to seabed (temporary or reversible effects)	Temporary (averaged between the years)	Shipping density	AIS data calculated directly to 1 km grid cells.	Average of total shipping density in a 1km x 1 km cell 2011-2014, log-transformed, normalized	rescaled with depth: 0-10 m= 100% 10-15 m= 50% 15-20 m= 25% 20-25 m= 10% 25m < =0%	Spatial extents, including spatial attenuation of the pressures, are calculated per specific data sets. Mean pressure intensity per grid cell is assigned to the grid cell. The final grid cell intensity is downweighted (by areal %) if the pressure area is smaller than the grid cell. Activities are weighted according to the

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

		Recreational boating and sports	Total fuel consumption of recreational boats modelled directly to 1 km grid cells.	Total fuel consumption of leisure boats modelled in SHEBA project. Fuel usage range in a 1km x 1 km cell in 2014, log-transformed, normalized	rescaled with depth: 0-5m= 100% 5-7 m= 70% 7-10 m= 50% 10-15 m= 10% 15m < =0%	method described in the document. All the pressure intensities of specific pressure layers are summed per grid cell.
		Extraction of sand and gravel	400 m buffer suggested	Average amount of extracted material over years, if value missing, 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Dredging	1 km buffer considered, point and polygon data converted directly to 1 km grid cells	Average amount of dredged material over years, if value missing 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Deposit of dredged material	1.5 km buffer considered, point and polygon data converted directly to 2 km grid cells	Average amount of deposited material 2011-2014, if value missing 25% percentile of the existing information is given, normalized	Weighted by the exposure map	
		Bathing sites, beaches	1 km buffer considered, point data on beaches converted directly to 1 km grid cells.	Amount of bathing sites in a cell, normalized	Not relevant	
		Wind farms (construction)	300 m buffer considered for windfarms under construction, polygon data converted directly to 1 km grid cells.	Location of wind farms under construction	Weighted by the exposure map	
		Cables (construction)	100 m buffer considered for cables under construction, line data converted directly to 1 km grid cells	Location of constructed cables, rescaled intensity to 0.6	Weighted by the exposure map	
		Pipelines (construction)	No pipelines under construction reported	No pipelines under construction reported	Weighted by the exposure map	
		Potting / creeling	Eventually 0.05 x 0.05 c-square degree grid (reporting unit for VMS data from ICES)	Average of potting/creeling intensity in 2011-2015 log-transformed and normalized (not included in initial tests)	Not relevant	
		Demersal long lining	0.05 x 0.05 c-square degree grid (reporting unit for VMS data from ICES)	Average of seabed surface contacting gear fishing intensity (Surface area ratio) in 2011-2013, logtransformed, normalized	Not relevant	

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

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent (*	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Changes to hydrological conditions (e.g. by	cumulative	Hydropower dams	a grid cell in the estuary	locations of hydropower dams - those that are operational and produces energy	Not relevant	Spatial extents and potential attenuation gradients are assigned to

constructions impeding water movements)		Water course modification	1 km buffer	Location of water course modifications	Not relevant	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.
		Wind farms	100 m buffer around each turbine	Location of operational wind farms as polygons	Not relevant	
		Oil platforms	100 m buffer around the platform	Location of oil platforms as points	Not relevant	
Inputs of continuous anthropogenic sounds (into water)	temporary	Ambient underwater noise	BIAS project ambient underwater noise data modelled into 0.5 km x 0.5 km grid	Ambient underwater noise of frequencies of 63, 125 and 2000 Hz exceeding noise levels 95% of the time in full water column during 2014	Not relevant	Average of decibels of 3 different frequencies
Inputs of impulsive anthropogenic sound (into water)	temporary	Impulsive noise events	Data converted directly to 1km grid cells	Data from HELCOM-OSPAR Database for impulsive noise and national data call (polygons, points, lines) with noise values categorized from very low, low, medium, high and very high	Not relevant	Average of events based on noise value codes
Inputs of other form of energy (electromagnetic waves)	temporary	Cables	No buffer considered, line data converted directly to 1 km grid cells	Location of cables	Not relevant	Not relevant
Input of heat (e.g. by outfalls from power stations) into water	temporary	Discharge of warm water from nuclear power plants	Gradual buffer around outlet	Average input of warm water (Celcius) from the nuclear power plant outlets	Not relevant	Sum of the input of warm water.
		Fossil fuel energy production (only location available)	Gradual buffer around outlet	Average input of warm water (Celcius) from the nuclear power plant outlets	Not relevant	

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent (*	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Input of hazardous substances	temporary	CHASE Assessment tool concentration component: results per assessment unit	HELCOM assessment units	Contamination Sum of the CHASE Assessment tool concentration component	Not relevant	Not relevant
Introduction of radionuclides	temporary	Discharges of radioactive substances	Gradual buffer around outlet to 10 km distance	Annual averages of CO60, CS137 and SR90 from the period 2011-2015 per nuclear power plant. Aggregation to be agreed intersessionally between HELCOM Mors Expert group and the Secretariat.	Not relevant	Not relevant

Oil slicks and spills	temporary	Oil slicks and spills from ships and oil platforms	Buffer area depending on reported spill area	If oil spill volume was missing (67/560), median of the rest was given. If area of spill was missing (103/560), mean of the existing was given. If the spill was < 1km2, the value of spill volume was given directly to 1km2 grid cell. If the spill area > 1km2, the estimated volume of the spill was divided by the spill area to get the estimated amount of oil / km2. This value was given to the entire spill area.	Not relevant	sum of spill volume
		Polluting ship accidents	point, converted directly to 1 x 1 km grid	9/24 accidents with oil spills were missing spilled oil volume, thus a mean of reported volumes was given to accidents with missing oil volume. Spill volume in m3 was converted to grid	Not relevant	
Inputs of litter[18]	temporary	Beach litter	points converted directly to 1 x 1 km grid	Beach litter indicator to be used as proxy for pressure. Presence/absence of beach litter	Not relevant	Sum of presence of beach litter and litter on sea floor
		Bottom trawled litter from seafloor	information converted directly to 1 x 1 km grid	DATRAS database on trawl surveys (ICES)	Not relevant	
Inputs of nutrients	temporary	Interpolated nitrogen and phosphorus concentrations (	Mean value per grid cell	N and P concentrations	Not relevant	Not relevant (separate data layers)
Inputs of organic matter	temporary	Riverine input of organic matter	plume based on satellite images	concentration based on different proxies (e.g. BOD, COD values)	Weighted by the exposure map	Not relevant

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent (*	E. Data used for analysis / data processing	F. Depth / exposure	G. Aggregation method
Disturbance of species due to human presence	temporary	Recreational boating and sports	Total fuel consumption of recreational boats modelled directly to 1 km grid cells.	Total fuel consumption of recreational boats presented as presence / absence	rescaled with depth: 0-10m= 100% 10-15 m= 70% 15-20 m= 50% 20-30 m= 20% 30-40 m = 10% 45m < =0%	Specific pressure layers first modified by spatial extents and depth influence. Each of them is considered as of equal importance (same weight). Calculate the sum of the pressure in a cell.
		Bathing sites, beaches	point data converted directly to 1 km grid cells	Location of beaches presented as presence / absence	Not relevant	
		Marinas and leisure harbours	point data converted directly to 1 km grid cells	Location of marinas and leisure harbours presented as presence / absence	Not relevant	

[18] It is still uncertain whether available data can be used to develop a spatial layer representing marine litter.

A. Aggregated pressure	B. Temporal nature	C. Spatial datasets to be combined	D. Spatial extent	E. Data used for analysis / data processing	F. Depth / exposure	G. Combination method
		Game hunting of seabirds	polygon data converted directly to 1 km grid cells	Game hunting of seabirds presented as presence / absence	Not relevant	
		Predator control of seabirds	polygon data converted directly to 1 km grid cells	Predator control of seabirds presented as presence / absence	Not relevant	
		Hunting of seals	polygon data converted directly to 1 km grid cells	Hunting of seals presented as presence / absence	Not relevant	
		Urban land use	polygon data converted directly to 1 km grid cells	presence / absence	Not relevant	
		Population density	coastal population density polygon data converted directly to 1 km grid cells	presence / absence	rescaled with depth: 0-4m= 100% 4-7 m= 70% 7-10 m= 50% 10-20 m= 20% 20m < =0%	
Extraction of, or mortality/injury to fish	temporary	Extraction of target fish species (cod, herring, sprat, flounder) in commercial fishery	Reported per ICES Rectangles, covers the whole Baltic Sea	Extraction of fish species (landings) per ICES rectangle, average of 2011-2014. Landings calculated per km2.	Not relevant	Log transformed. For cod, recreational fisheries catches were added (see below).
		Extraction of fish species by recreational fishery	Reported per country for eel, cod and salmon (tonnes).	Extraction of fish species by recreational fishing, average of 2011-2014. For cod, recreational landings (tonnes/km2) were added to commercial catches.	Not relevant	Tonnes/km2 values for cod, summed with tonnes/km2 values from commercial catches. Log transformed.
Extraction of, or mortality/injury to seabirds (e.g. hunting, predator control)	temporary	Game hunting of seabirds	Varying reporting units, from counties to HELCOM subdivisions	Species summed together, average of killed seabirds of years 2011-2015 per reporting unit, numbers of killed birds / km2 calculated and generalized for the whole reporting unit, normalized	Not relevant	normalized values summed together
		Predator control of seabirds	Varying reporting units, from counties to HELCOM subdivisions	Total number of killed cormorants per year averaged for 2011-2015, numbers of killed birds / km2 calculated and generalized for the whole reporting unit, normalized	Not relevant	
Extraction of, or mortality/injury to mammals	temporary	Hunting of seals	Varying reporting units, from counties to HELCOM subdivisions	Total number of killed seals (per species) averaged for 2011-2014, numbers of killed seals/ km2 calculated, and generalized for the whole reporting unit, normalized	Not relevant	Not relevant (as the species are presented separately in the ecosystem components)
Introduction of non-indigenous species and translocations	cumulative	Spread of non-indigenous species	Reported per coastal areas	Number of NIS per HELCOM sub-basins and coastal areas, generalized for the whole reporting unit.	Not relevant	Not relevant

Change in climatic conditions		Long term change in sea surface salinity (PSU), and sea surface temperature (degrees Celsius)	Point data covering the Baltic Sea	Long-term monitoring data on sea surface salinity and temperature from ICES database. Coastal monitoring sites (<2km to land) excluded. Mean of July-August values at 10m depth (surface) calculated for 1960-2010 (presenting long-term) and for 2011-2015 (assessment period) per HELCOM sub-basin. Change in temperature and salinity calclulated. Temp. increase is expected with climate change, thus subbasins showing decrease are given 0 values. Data normalized. Salinity decrease is expected with climate change, thus subbasins showing increase, are given 0 values. Data normalized.	Not relevant	Not summed (as change in temperature is likely to have different effects on the ecosystem, than change in salinity)
Acidification		Long term change in pH	Point data covering the Baltic Sea, some sub-basins missing data on pH (Great Belt, the Sound, Kiel Bay, Arkona Basin)	Long-term monitoring data on pH from ICES database. Coastal monitoring sites (<2km to land) excluded. Mean of July-August values at 10m depth (surface) calculated for 1960-2010 (presenting long-term) and for 2011-2015 (assessment period) per HELCOM sub-basin.. Change in pH calclulated. Normalized.	Not relevant	Not relevant