Cost effectiveness of proposed new measures for the Baltic Sea Action Plan 2021

ACTION

Co-funded by the European Union

Monitoring and assessment

2021

HELCOM

ACTION

Co-funded by the European Union

This publication has been produced as part of the project "Actions to evaluate and identify effective measures to reach GES in the Baltic Sea marine region (HELCOM ACTION)". Running from January 2019 to December 2020, HELCOM ACTION is a Helsinki Commission (HELCOM) coordinated project that is co-funded by the European Union. The project is designed to contribute to the update of the HELCOM Baltic Sea Action Plan by 2021 and can also be used by HELCOM Contracting Parties that are also EU Member States in updating and implementing their MSFD Programme of Measures. Information and views expressed in this publication are the authors' own and might vary from those of the Helsinki Commission or its members.

helcom.fi/helcom-at-work/projects/action/

This publication is a deliverable of the HELCOM ACTION project's work package WP6 - Sufficiency of measures: developing an approach to assess the sufficiency of existing measures to achieve GES, implementing the approach for selected topics, identifying the need for new measures, estimating cost-effectiveness of tentative new measures

For bibliographic purposes this document should be cited as:
Cost effectiveness of proposed new measures for the Baltic Sea Action Plan 2021. HELCOM ACTION (2021)

Contibutor(s): Saikkonen L, Lai T-Y, Oljemark K, Laamanen, L, Korpinen S, Ahtiainen H, Bastardie F, Dodd L, Kikas L, Kraufvelin P, Markager S, Pakalniete K, Vretborn M, Wolf J.

General information about the HELCOM ACTION project

EU programme concerned
Marine Strategy Framework Directive - Second Cycle: Implementation of the New GES Decision and Programmes of Measures

Reference number of the call for proposals
DG ENV/MSFD 2018 call

Title of the project
Actions to evaluate and identify effective measures to reach GES in the Baltic Sea marine region (HELCOM ACTION)

Grant agreement number
110661/2018/794637/SUB/ENV.C2

Name of beneficiary of grant agreement
Baltic Marine Environment Commission – Helsinki Commission (HELCOM)

Official legal form
Intergovernmental Organisation

Official registration number
Not applicable

Official address
Katajanokanlaituri 6B, 00160 Helsinki, Finland

Name and title of the Project Coordinator
Owen Rowe, Project Manager

Name of partners in the project and abbreviations used
Finnish Environment Institute (SYKE)
Technical University of Denmark (DTU)
Aarhus University (AU)
Tallinn University of Technology (TTU)
Swedish Agency for Marine and Water Management (SwAM)
Swedish University of Agricultural Sciences (SLU)
University of Tartu, Estonia (UT)
Klaipėda University, Marine Research Institute (KU)

Sub-contractors
Baltic Nest Institute (BNI), Sweden
AKTiiVS, Latvia
Bionautit, Finland

Start date and end date of the reporting period
01/01/2019 – 31/12/2020

Start date and end date of the project
01/01/2019 – 31/12/2020

Cost effectiveness of proposed new measures for the Baltic Sea Action Plan 2021.

Contents

1. Background

HELCOM has started a process to update the Baltic Sea Action Plan (BSAP) by 2021. The Contracting Parties and observers were invited to propose new measures to the update process and multiple steps were set up to filter, analyze and further define the proposals[1]. In this report, the proposed new measures were analyzed in terms of their costs, effectiveness to reduce pressures and improve state and as their total sufficiency to reach good state.

The cost effectiveness analysis for new measures analyzes the costs and effectiveness of new measures separately, compares measures with respect to their costs and effectiveness, and assesses the sufficiency of existing and proposed new measures as well as the total costs of proposed new measures. The sufficiency is assessed as improvements in environmental state and reductions in pressures that can be achieved with existing and new measures in the Baltic Sea, and whether these are sufficient to achieve a good state of the marine environment. The effectiveness to reduce pressures and improve state is estimated individually for the new measures. The effectiveness and sufficiency analysis for new measures applies the framework of SOM analysis for existing measures (HELCOM ACTION 2021a, HELCOM ACTION 2021b) but takes into account both existing and new measures. The sufficiency analysis estimates whether good state of the marine environment will be achieved in 2030 with existing and all proposed new measures. The main aim of the sufficiency analysis for the new measures is to indicate both thematically and spatially where new measures will likely be sufficient and where gaps will still prevail. The effectiveness analysis focuses on the effectiveness and impacts of individual new measures as well as on their overlaps with respect to pressures and human activities that these measures target.

The SOM analysis was developed by the ACTION project and was first applied to existing measures, i.e. measures that have already been agreed and are affecting the environment until 2030, in the Baltic Sea region (see ACTION WP6.1 reports). The same overall approach was applied to the new measures across all topics included in the cost-effectiveness analysis (except litter and land-based nutrient inputs) to ensure comparability and coherence of the results for existing and new measures and to pilot the approach for cost-effectiveness analysis. The main components of the SOM analysis for existing measures included assessing the contribution of activities to pressures, the effect of existing measures on pressures from activities, the effect of development of human activities on activities, and the effect of changes in pressures on environmental state. The SOM approach, model and data collection are described in detail in the SOM methodology report (HELCOM ACTION 2021b).

[1] FISH 11-2020, AGRI 9-2020, MARITIME 19A-2020, PRESSURE 12-2020, GEAR 22-2020, STATE & CONSERVATION 12-2020, STATE & CONSERVATION 12A-2020, PRESSURE 12b-2020, AGRI 9b-2020, PRESSURE 12c-2020, HELCOM BSAP UP WS-HZ 2020, HELCOM BSAP UP WS-EUTRO 2020, HELCOM BSAP UP WS-BIO 2020, HELCOM BSAP UP WS-SEA 2020, STATE & CONSERVATION 13-2020, MARITIME 20-2020, PRESSURE 13-2020, RESPONSE 28-2020, AGRI 10-2020, GEAR 23-2020, FISH 12-2020

For the new measures, effectiveness was estimated by linking the measures to similar existing measure types used in the SOM analysis, or by assessing their effectiveness based on the information included in the proposals for new measures (so called synopses) and other literature. Otherwise the data and approach used to analyze the effectiveness and sufficiency of new measures are the same as for the existing measures.

Economic feasibility of the new measures was estimated based on their costs. The costs were estimated for the entire Baltic Sea region and together with the sufficiency and effectiveness results - they can be used to indicate which new measures could potentially be economically feasible for the Baltic Sea Action Plan and to estimate the magnitude of the total costs of all new measures. However, there are significant gaps in the data for effectiveness and costs of new measures as well as on their uncertainties and therefore the quantitative results are no more than indicative. Also, some of the linkages between pressure reductions and state improvements could not be sufficiently defined for the SOM analysis and therefore the reductions of these pressures do not show in the results describing improvements in state. These were also the main reasons why further optimization of measure sets was not included in this analysis. However, the analyses presented in this report provide and pilot heuristic tools for optimal choice of measures that assess individual impacts of measures as reductions of pressures affecting state compared to costs, and overlaps of measures with respect to activities and pressures.

2. Data and methods

Proposed new measures and overview of methods

There were originally 133 proposals for new BSAP measures (i.e. the synopses, guidance document SOM Platform 2-2019 4-2), but the HELCOM Working Groups only considered 100 of them as measures or steps towards measures, which were concrete enough for evaluation of the effectiveness and costs. The remaining 33 proposed synopses were not considered as measures, such as data collection, knowledge sharing, map creation or focusing on monitoring, and these were not included in this analysis. After this, HELCOM arranged thematic expert workshops to evaluate the effectiveness of the proposed new measures to improve the state of marine environment and other effects that influence climate and other parts of the environment. The results of the SOM analysis for existing measures were presented in these workshops. In this report, the same approach for sufficiency of measures was used as for the existing measures. The ACTION project carried out an analysis on the cost effectiveness of new measures. The analysis took into account the recommendations of the previous HELCOM work (i.e. analyses and considerations by the working groups and workshops, see above). Before analysing the measures, some data treatments were necessary.

First, the new measures were linked to human activities, pressures and state components (see method description below). The links are shown in Appendix A. Second, it was recognized that some of the measure proposals will not influence the entire Baltic Sea (e.g. bottom trawling takes place only south of Gotland and harbour porpoise does not occur in the Bothnian Bay). Therefore, the analysis excluded some areas for some measures. The geographical areas relevant for measures ('geographical extent') are shown in Appendix A and B. Third, effectiveness and cost of some the new measures depends on the number and/or size of sites they will be applied in. This is called 'application extent' of the measure. The forms of the application extent are various. For instance, the measure for artificial wetlands can be applied in some hundreds to some thousands of water treatment sites, the measure for dam removal could be removing hundreds of blocks, and the measure for mussel farm can be up to hundreds km^2. To allow for any quantitative analyses, three application extent scenarios were created to all such measures (see part 1 below). Only 83 measures were included in the actual analysis, since measures targeting land-based nutrients were excluded for reasons discussed later in this report.

Finally, some of the 83 measures were thematically overlapping. These were identified by the HELCOM working groups and by the ACTION project. If multiple measures overlapped thematically, the measures were combined and new names were assigned to the groups of measures. In the sufficiency and effectiveness analyses, the grouped measures were still included as individual measures of the same measure type so that only the most effective measure of the combined measure had an impact on pressures and state improvements. The grouped measures included in the analyses are given in Tables 4-11 and the original measure names are given in the footnotes of the table. Appendix B shows the measure names and IDs before and after grouping. *From now on the measure groups will be referred to by term 'measure'.*

The cost-effectiveness analysis consists of following three parts:

1. **Costs and effectiveness of individual measures.** Effectiveness of individual measures was assessed as the impact of reducing pressures on the entire Baltic Sea scale. Also costs were estimated for the whole Baltic Sea region. As described above, three scenarios were used for application extents of measures (Low, Medium, High). These scenarios define the spatial extent of application of the measures in the relevant sub-basins and/or countries (Geographical extent) of each measure. The application extent in the three scenarios were quantified using expert judgment by the ACTION project and they were based on experiences of previous projects testing and evaluating such measures. All reported results are for the medium scenario, but effectiveness results for the other scenarios are provided in Appendix A. Determinations of the application extents for the measures are described in Appendix B, and these were used to quantify both effectiveness and costs. For some measures also geographical extent was defined, which excluded non relevant areas where the measure would be non-applicable. Also these are described in Appendix A.

2. **Cost-impact ratios for individual measures.** In the cost impact ratios, the impact of a measure was calculated based on its ability to reduce pressures that are significant for state components and then compared to the expected costs of the measure. Also, the overlaps between measures regarding human activities and pressures that the measures target were quantified. These results can be used to identify potentially optimal measures to improve state and to avoid overlaps of measures with respect to activities and pressures.

3. **Sufficiency, impacts and total costs of all measures.** Total reductions in pressures and sufficiency of the existing and proposed new measures to reach good state were analyzed and total costs were calculated.

Effectiveness of proposed new measures

Effectiveness of the new measures to reduce pressures from human activities (in %) or to directly increase probability of improvements in state (in %) were estimated using existing literature (incl. the synopses) sources that allowed the quantification of measure effectiveness. The literature estimates were supplemented by linking the new measures to similar measure types defined for the SOM analysis of existing measures and using the same effectiveness estimates that were used for the measures of this type in the SOM analysis for existing measures. These linked effectiveness values were based on expert elicitation (see HELCOM ACTION 2021b). The effectiveness values based on the literature review and links to existing measure types are given in Appendix B. The expert-based estimates were used for those measures where estimates based on literature data were not available. The collection of expert based data for the effectiveness of measure types and the calculation of effectiveness values based on this data is described in the methodology document for SOM analysis (HELCOM ACTION 2021b). For the literature-based effectiveness scalar values which did not include any estimate of uncertainty, the minimum and maximum effectiveness values were set to 60% of the most likely or average measure effectiveness, based on the average standard deviation of effectiveness of measure types in the SOM analysis for existing measures. The application extents, measure effects and costs (in appendices A and B) were scaled so that multiplier equaling 1 was used for medium extents and a multiplier lower than or equal, or higher than or equal to 1 was used for low and high application extent scenarios. This multiplier is used to multiply the effects of measures according to the chosen scenario. The technical implementation (code) of the SOM analysis and modifications required to analyze the effectiveness of new measures and sufficiency of new measures will be uploaded to GitHub.

The effectiveness of the new measures was estimated in two different ways: (1) the impacts as Baltic wide pressure reductions (%) resulting from the implementation of an individual measure, and (2) the impact of a new measure as a %-reduction of the total pressure consisting of pressures that are significant for state components and as a %-reduction in the total pressure gap to achieve the good state. The reduction in gap was defined as the relative reduction in the gap between the expected total pressure reductions resulting from existing measures and expected total pressure reductions required to achieve good state, noticeable improvement in state, or %-improvement in state. These different state improvement specifications were used following the topic structures of the SOM analysis. The impacts measured as the ability of a measure to reduce total pressure and to close the gap were used to compare the measure impacts to the costs. Total pressure reduction consists of reductions in those pressures that are significant for a given state component with respect to not being in good or improved state. It is, however, good to notice that not all of the measure impacts on pressure inputs could be quantified as improvements in state in the SOM analysis (HELCOM ACTION 2021b).

In 1) the pressure reduction impacts, the effectiveness does not regard whether the pressure reductions resulting from new measures are significant to any state component, but these pressure reduction impact results take into account the contributions of activities to pressures and sum the pressure reductions from different activities. They are defined based on the human activity development scenario, where

there is no projected change in the extent of activities by 2030 to highlight the impacts of measures explicitly. The pressure reduction impacts were defined for all pressures that have any quantified measure effectiveness estimates. However, some of the identified measure effectiveness estimates for reducing pressures from activities could not be quantified, or they do not affect the activities that are contributing to the given pressure. The results with missing effectiveness estimates are marked in the results.

2) The impacts of individual measures to reduce pressures that are significant state for components were assessed both in "absolute" %-terms (TRN), and as relative %-reduction in gap between the total pressure reduction resulting from existing measures and total pressure reduction required for good state (or noticeable improvement in state or % improvement in state) (RR) (see figure 1). The impact is defined in two different ways, as TRN and RR to illustrate how the definition of the impact affects the results on measure impacts and cost impact ratios. The relative reduction in GAP has been used in previous analyses to define the impacts and cost-effectiveness of measures (see for example Oinonen et al. 2016). Total pressure reduction of a measure (TRN) in absolute %-terms is defined as the sum of average total pressure reductions over all assessed topics K:

$$TRN = \sum_{k \in K} TRN_{\mathrm{k}}$$

Where average total pressure reduction per topic TRN_k is defined as average total pressure reduction of all state components within that topic J_k:

$$TRN_{\mathrm{k}} = \frac{\sum_{\mathrm{j} \in J_k} TRN_j}{N_{\mathrm{k}}}$$

Where average total pressure reduction of a state component TRN_j is the average total pressure reduction for all assessment areas/populations of the given component I_j:

$$TRN_j = \frac{\sum_{i \in I_j} TRN_i}{N_j}$$

Where TRN_i is the total pressure reduction for the given assessment area/population i of the state component. The relative %-reduction in gap between the total pressure reduction resulting from existing measures and total pressure reduction required for good state (or noticeable improvement in state or % improvement in state) (RR) is defined as follows

$$RR_i = \left(\frac{TRN_i}{GAP_i - TRE_i}\right) \times 100\%$$

To calculate the sum of average relative reductions over all assessed topics, one can replace TRN_i with RR_i in the formulas for the averages. The total pressure reduction required for good state is denoted by GAP_i and TRE_i is the reduction in pressure resulting from existing measures. The numbers of assessment areas for each state component and state components per topics are denoted by N_j and N_k respectively. The impacts are illustrated in Figure 1 where the relative reduction in the gap RR can be defined as the light green area on the right (TRN) divided by the red area below the GES threshold in the middle (GAP-TRE).

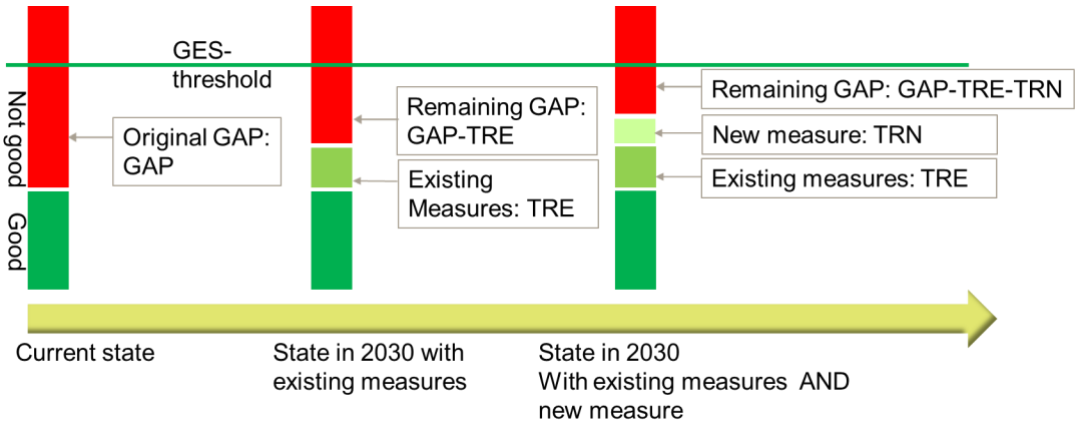

Figure 1. Conceptual figure explaining the components used to calculate the impacts (TRN and RR) of individual measures to reduce total pressure consisting of pressures that are significant for state components.

Total pressure reduction consists of reductions in those pressures that are significant for given state component with respect to not being in good or improved state[2]. These impacts were compiled for each new measure and state component that has sufficient information on the pressure state linkages, by calculating the total pressure reduction resulting from the implementation of the new measure for significant pressures following the SOM methodology. The total pressure reductions and impacts on closing the gap for state components were aggregated for the whole Baltic Sea region by taking an average of the results for different state assessment areas/populations. The impact value of closing the gap for a state component thus describes how effective separate new measures are on average in closing the gap between the expected total pressure reduction resulting from existing measures and expected total reduction required for the desired environmental state.

The pressures included in the total pressure reductions are those for which a decrease in the input of pressure resulting from a measure has an equal impact on the effects of pressures on the state component. These pressures differ by state components and for new and existing measures and all state components include physical disturbance and loss of marine habitats; input of continuous noise; waterbird bycatch; porpoise bycatch; targeted extraction and bycatch of coastal fish, flatfish and seatrout; waterbird disturbance and displacement; disturbance of species: obstructions-sea trout; intentional killing of waterbirds; and input of hazardous substances.

The impacts defined as total pressure reduction and effectiveness in closing the gap take into account the effectiveness of measures in reducing pressures from activities, contributions of pressures from activities, and the significance of different pressures to state components as well as the pressure reductions resulting from existing measures and pressure reductions required for a good state or a state improvement. The total impacts of each measure for all assessed state components are calculated as the sum of average impacts on state components of different topics. The cost impact ratio is

[2] The significances of pressures for all pressures for each state component can be found in the SOM topic reports for the existing measures

defined by comparing the total impact value to the costs of the measure, by dividing the costs of the measure by the total impact.

Costs of the new measures

The cost estimation was divided into four steps: (1) Identification of sub-measures and cost types for sub-measures, (2) Cost data collection, (3) Cost transfer, and (4) Cost estimation of the new measures.

(1) Identification of sub-measures and cost types for sub-measures:

After the overlapping measures were grouped, the sub-measures of each grouped measure and cost types of the sub-measures were identified based on information included in the proposals for new measures, available in the HELCOM workspace, and the technical review results from the Working Groups [3]. Some grouped measures include multiple sub-measures. For example, the measure group of "Regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea" includes a supporting sub-measure to carry out studies to assess the impacts of the regulation establishment and the follow-up implementation, a supporting regulatory sub-measure of establishing the relevant regulation, and two types of technical measures that can be implemented if the regulation is established. Some grouped measures only contain one technical measure, such as mussel farming to reduce nutrients at sea. Each sub-measure contains one to multiple cost types listed below:

Financial – Capital costs of a measure: fixed one-off expenses incurred by the purchase of some tangible or intangible goods that can be used over a longer period. For example, a capital cost can be the cost to purchase a boat for mussel farming.

Financial – Operation and maintenance (O&M) costs of a measure: These apply for the institution/sector/agent that is implementing the measure. For the implementing institution, financial costs include direct costs, such as labour costs for maintaining mussel farms.

Financial – increase in daily business/operation costs: referring to the increase of original daily business cost due to the implementation of new measures. For example, increased transportation due to closed fishing grounds.

Financial – Indirect costs of implementing a measure: such as overhead costs of an institution or the depreciation costs of general multipurpose monitoring equipment when implementing a new measure.

[3] HELCOM PRESSURE 12th meeting on 21-24 April 2020: https://portal.helcom.fi/meetings/PRESSURE%2012-2020-734/MeetingDocuments/6-4-Att.1-Rev.1%20Review%20of%20synopses.xlsx; HELCOM MARITIME 19Ath meeting on 14-15 April 2020: https://portal.helcom.fi/meetings/MARITIME%2019A-2020-713/MeetingDocuments/3-8%20Rev.%202%20Att.%20Review%20of%20synopses%20on%20new%20HELCOM%20actions.xlsx; HELCOM State & Conservation 12th meeting on 11-15 May 2020: https://portal.helcom.fi/meetings/STATE%20-%20CONSERVATION%2012-2020-740/MeetingDocuments/3J-5-Att%201.%20Rev.2%20Technical%20review%20of%20synopses.xlsx.

Financial – Other costs: such as administration cost for the authority responsible for administration.

Opportunity costs – foregone revenues: for example, a measure that restricts fishing in a certain area can decrease the profitability of the fishing sector, and this economic loss is an opportunity cost resulting from such a measure.

Cost saving – Decrease (save) in daily business/operation costs: referring to cost saving in the daily business operations due to the implementation of a measure.

Cost saving – others

Identification of sub-measures and cost types can indicate directions for cost data collection (step (2)) and help clarify which parts of costs are missing in the cost estimation (step (4)). The information of sub-measures, cost types, and cost for each sub-measure are summarized in the summary sheet in Appendix C. The result section in this report only presents the total cost of grouped measures and the cost types that were possible to be included in the total cost of each grouped measure. Indirect costs and cost saving are not included in the total cost.

(2) Cost data collection:

Cost data were collected from the following sources:

- The cost descriptions and references provided in the proposals for the new measures (see HELCOM workspace (link).
- The literature reviewed for the effectiveness of existing and new measures. Some of the reviewed literature also contains cost data. See Appendix B for these references.
- Cost data provided by ACTION WP2
- Reviewing the cost estimates and relevant studies conducted for the Finnish Water Framework Directive.
- Cost collected from the national Programme of Measures (PoM) survey under the Finnish Marine Strategy. Some proposed Finnish MSFD measures partly or completely overlap with the new BSAP measures, and thus some of the cost estimates could be used.
- A data collected by project partners, HELCOM Contracting Parties and HELCOM expert network on economic and social analyses (EN ESA) representatives. The Contracting Parties that provided cost estimates were Estonia, Latvia, Lithuania and Sweden.
- Conducting specific literature searches for proposed measures where the cost types of the sub-measures were described concretely enough to define cost items.
- The collected cost data are provided in Appendix C (Cost input data sheet), which records the cost types, affected actors, references, assessment value, assessment time, and other relevant information of each collected cost item.

(3) Cost transfer:

The collected cost data estimates were originally assessed for different countries and they are based on different assessment years. Therefore, it was needed to (1) transfer the unit cost to the same reference year and (2) transfer the unit cost from the study country/countries that the cost estimate was defined for to other countries that would implement the measures (called "policy country" in the rest of the report). The cost transfer was conducted by following three steps:

(a) calculation of the annualized unit cost from the cost data:

When the cost type was categorized as capital cost, an equivalent annual cost was calculated with the lifetime given by the original estimation and 3% interest rate[4]. If the capital cost had been annualized and the provided information from the original study was not enough to calculate the original one-time cost, the annualized cost from the estimation was used. For other types of costs, the annual cost was calculated by dividing the total cost by the numbers of years used in the original estimation. The original estimation sometimes was shown in total cost for a region or a project. The total cost was transferred to unit cost, which varies by measures, for example, EUR/km^2 per year, SEK/country per year, or USD/vessel per year, etc. For some cost data that was not presented with respect to time (e.g., EUR/m^3 of wastewater emission), the annul quantity (e.g., emission amount per year) was used in step 4 to define annual costs.

(b) Transfer the unit cost to 2019 price level:

The annualized unit cost was further transferred to 2019 price level, by using the consumer price index (CPI) of the study country defined by OECD (2020a). The ratio between CPI in 2019 and CPI in the study year ($CPI_{2019}/CPI_{\text{study year}}$) was used. If the cost was already estimated at the Baltic Sea level, an average CPI of the 9 countries was used. If the cost was estimated based on several countries globally, an OECD average CPI from OECD (2020a) was used.

(c) Transfer the cost to policy countries and to EUR:

The unit cost in 2019 price level was further transferred to each country that would implement the new measure. The adjustment is based on purchasing power parity (PPP) since the input prices, and tradable and non-tradable components of the collected cost items were difficult to identify (Hutton & Baltussen, 2005). In addition, unlike for benefit transfer that needs to consider the demand and welfare differences across different countries (Brander, 2013), adjusting cost with the gross domestic product (GDP) is not needed for cost transfer (Hutton & Baltussen, 2005). In principle, the following function was used to transfer the cost using PPP adjusted exchange rate:

$$Cost_{policy\ country} = Cost_{study\ country} \times \left(\frac{PPP_{policy\ country}}{PPP_{study\ area}}\right) \times ER \quad \text{.....(1)}$$

[4] Many studies have reviewed that 3%-8% discount rate was used in the guidance for EU countries before 2010 (OECD, 2007, Evans & Sezer 2005, Kazlauskiene, 2015). Based on the guidance by OECD 3% or even lower discount rate can be used for overall discount rate in short to medium term (OECD, 2018). Therefore, 3% was decided to be used for the analysis.

PPP ratio changes the cost from the local currency of the study country to the local currency of the policy country. ER is the exchange rate from the local currency of the policy country to EUR. The equation (1) is applicable for all study countries no matter if the local currency of the study country is EUR or non-EUR currency. However, the local currency used in the policy countries and the currency of the original cost estimate influenced the way the equation (1) was applied. Table 1 summarizes how equation (1) should be used in different cases. In addition, if the study country is also one of the countries that should implement the measure, the collected cost was not only the transferred to other policy countries but also used as the cost for the given country in step (4). In the latter case, if the currency of the study country is not EUR, the cost needs to be transferred to EUR with ER before proceeding to the step (4). Both PPP (EUR27=1) and ER in 2019 were based on PPS defined by EUROSTAT (EUROSTAT, 2020a; 2020b). For those countries that PPP was not defined by EUROSTAT, the PPP from OCED (2020b) that convert the price to USD combined with the PPP that can transfer USD and the price level to EUR in EUROSTAT were used. All the parameter values used for cost transfer can be found in Appendix C.

Table 1. Different conditions to apply equation (1)

Is the currency of the policy country EUR	If the collected cost is defined as local currency of the study country	How to use equation (1)
No	Yes	Apply equation (1) directly
No	No	The collected cost should be transferred back to local currency with exchange rate before applying the equation (1)
Yes	Yes	Apply equation (1) directly, but ER = 1
Yes	No	Transfer original cost back to local currency with exchange rate before applying the equation, and ER =1

(4) Cost estimation for the new measures:

In general, the costs of the new measures were estimated by multiplying the transferred unit cost with the quantity unit (application extent) of the new measure. However, the unit of collected cost and application vary by measure and thus influence the actual calculation procedure. The application of each new measure for the entire Baltic Sea is based on relevant sub-basins, application extents, and data used for effectiveness estimation (details are described in Appendix A and B). Few examples of the factors that affected the cost estimations for measures are provided in Table 2. In addition to the unit cost that is area-based (e.g., EUR/ha or EUR/country), the sub-basin shares or the catchment shares of the countries were used to weight the quantity for each country. For example in Table 2, the measure "Mussel farming to reduce nutrients at sea" was perceived relevant for all sub-basins expect the Bothnian Bay and the estimated total application area in the medium scenario of application extent was 4000 ha in the relevant sub-basins. The total areas of sub-basins and the shares of each country of these sub-basins were used to divide 4000 ha for each country to multiply with the transferred unit cost (from step (3)) to get the total cost of each country. The total cost for the Baltic Sea is the sum of the total costs for all countries that are assumed to implement the measure. Catchment share is used for land-based measures, for instance, the measure of "Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies". For some measures, the unit cost was not area-based, such as the measure "Reduce harmful impact of grey water discharges from Baltic Sea shipping" but the cost was presented for example as EUR/vessel or EUR/m^3 grey water produced. In these cases, the quantity in units defined for the entire Baltic Sea was used with the unit cost transferred to Danish price in step 3, since Denmark is the country that has the highest price level among the HELCOM countries.[5] For the few measures that the unit quantity information from effectiveness analysis was not concrete enough, some further assumptions were made to calculate the costs. Such assumptions are reported in the Summary sheet in Appendix C. For some measures, there were multiple cost estimates for one measure with different kinds of cost units. In such case, the total cost was first calculated for each of the original estimate cost data sources and then by taking an average of the total costs to get a final total cost of a measure.

[5] Using Danish price as reference will likely lead to overestimation of the cost of this type of measure. However, it is not suitable to use "average" PPP as the equation (1) transfers the cost into local currency of the policy country. It will create a currency problem if "average" PPP is used.

Table 2. Examples of different factors affecting the total cost estimation for new measures

Example measure	Geographical extents	Medium scenario of the application extent	Quantity data used for effectiveness estimation	Further assumptions for cost estimation	Unit cost	Approach to estimate total cost
Mussel farming to reduce nutrients at sea	All sub-basins except the Bothnian Bay, all countries (9)	4000 ha	-	-	EUR/ha	1. Allocate 4000 ha to different countries based on area shares of the relevant sub-basins 2. Multiply the quantity of each country with the transferred unit cost for each country 3. Sum up the cost of all countries
Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies	All countries (9)	Sub-measure 1 (nutrient): 500 sites, each site 0.1km^2 (=5000ha) at catchment areas	-	-	EUR/ha	1. Use the catchment shares (Räike et al., 2019) of each country to divide 5000ha (at catchment) and 500ha ha (at WWTP) to get the area of each sub-measure for each country 2. Multiply the quantity of each sub-measure of each country with the transferred unit cost of each country
		Sub-measure 2: 50 WWTP (microplastics) or 10% of WWTPs (hazardous substance).	-	1. 10% of WWTPs ≈50 WWTP in the Baltic Sea area (Räike et al., 2019) 2. Assume that each WWTP constructed 10 ha of wetlands		

						3. Sum up the costs of all sub-measures and all countries
Reduce harmful impact of grey water discharges from Baltic Sea shipping	Whole Baltic Sea	-	90 cruise ships	In addition to 90 cruise ship, also 7033 cargo ships were considered (Boteler et al., 2015)[6]	EUR/vessel	Multiply the quantity for the entire Baltic Sea with the unit cost that has been transferred to Danish price level
Harvesting of reed and excessive vegetation (Can be any new measure)	3 countries: Sweden, Finland and Estonia)	-	-	-	EUR/country	1. Multiply the basin shares for the countries that would implement the measure with the transferred unit cost of each country 2. Sum up the cost of all countries that should implement the measure

[6] In principle, the cost estimation used the same quantity used for effectiveness. However, in this example case, the effectiveness of the measures cannot be estimated from the SOM results, so a further assumption was used to make the estimation scope more close to the description from the original proposed documents.

Sufficiency of the new and existing measures to reduce pressures and to achieve good state

The SOM analysis estimates how much pressures will be reduced and what is the probability that good state will be achieved with the existing and proposed new measures. If the thresholds for good state are not known, there were two alternative approaches: (1) probability that a noticeable improvement in state is achieved and (2) that a 10%/25%/50% improvement in state achieved (see HELCOM ACTION 2021b).

The sufficiency of measures (SOM) analysis for all proposed new and existing measures follows the methodology and approach described in the WP6.1 report of the SOM analysis and the methodology report. The SOM analysis is based on links between measures, human activities, pressures and state components. Each measure is assumed to reduce pressures or improve state through either one or more human activities or directly, and consequently the pressures and total pressures with respect to state components will be reduced and the state will improve. The unit of pressure reductions, state improvements and probabilities to reach good state is the % change, generally between 0-100%.

The projected pressure reduction results were compiled for pressure specific assessment units consisting of one or multiple basins (see topic specific reports of SOM analysis), but for feasibility they are reported for each sub-basin. It is assumed that for each basin of the same assessment unit, the projected pressure reduction is equal. Basin specific reductions in pressures are used to calculate the total pressure reductions for the Baltic Sea and improvement in state with respect to state components and their assessment areas/populations. The sufficiency of measures analysis results for new and existing measures in this report are described in Table 3.

Table 3. Key outputs of the SOM model.

Model output	Indicative use for the BSAP UP process
Pressure reductions (%)	Indicates how much all the measures (existing and new) in total reduce each pressure in each assessment unit.
Total pressure reductions with respect to state components (%)	Indicates reductions in total pressure, consisting of pressures significant for the state component not being in good environmental state.
Probability to reach good state, noticeable improvement in state, or %-improvement in state (%)	Indicates (increase in) the probability to reach good state or improvement in state with respect to different state components.

The results and data of the analysis have uncertainties and limitations which originate from the assumptions of the analysis, and from the deviances and gaps in the input data. A lot of these uncertainties are discussed in the specific SOM topic reports for the existing measures. For the new measures their effectiveness is based on measure synopses, reviewed literature values and the expert-based effectiveness estimates collected for the existing measures. The variability of this data and the data gaps cause further uncertainty. Therefore, the results should be looked at being focused on the big picture; what are the differences in magnitude of results and which pressures or states are improved by new measures (and which are not). It also has to be noted that for several new measures some of the identified measure effects on pressures from activities are lacking estimates of numerical effectiveness and thus these effects do not show in the results. These missing effects are reported in the corresponding tables.

Presented methods further allow the optimization of measure sets with respect to sufficiency and costs. However, due to gaps in data with respect to costs and quantified linkages for measure-activity-pressure-state chains, as well as to limited resources, optimization was not conducted within this analysis. Measure set optimization based on costs and sufficiency for measure-activity-pressure chains with joint measure effects has been previously piloted for plastic litter in Finland (Saikkonen, 2018).

3. Costs and effects of individual new measures

Costs of the proposed new measures

Figure 2 shows that the cost ranges for the new measures can be large. For some measure groups, the differences between lower and upper bounds are over 100 times. The uncertainty of the cost ranges results from (1) the uncertainty of the original cost data and the multiple sources of cost used for estimation, (2) the variety of the technical measures that are applicable to the proposed new measures and (3) the assumptions of cost estimation for some of the measures (see Summary sheet in Appendix C).All the cost presented in the report are for the medium application extent scenario, and thus uncertainties in the costs do not stem from the spatial extent of measure application.

The most costly measures were generally related to large-scale restoration of benthic habitats (e.g. G28, G30, G31 and G35 in Figure 2 and Table 4). However, total costs of all these restoration measures directly depend on the extent of application. These cost results are calculated for the medium scenario of the application extent (see Appendix B for the scenarios). Also measures reducing discharges from ships were estimated as costly (G01 and G02 in Figure 2 and Table2). The estimated cost for measures related to the ship discharge are likely overestimated because (1) the unit costs for these types of measures were based on the Danish price level (see explanation in the method section), and (2) some of the applicable technical measures are costly, which increases the upper bounds and the average of total cost. Implementing these measures in reality may include technical measures with lower costs. However, the proposal document for these measures does not indicate how different technical measures will be chosen. Therefore, the extreme assumption was used to estimate the boundary of the cost (the assumption can be found in the Summary sheet in Appendix C).

Some less costly measures are related to regulations of human activities such as fisheries (e.g. closures, gear regulations; G09, G10, and G15 in Figure 2), dredging (e.g. silt curtains, limited dredging effort; G22, G25, and G26 in Figure 2) or boating (e.g. speed and movement limits; G21 and G23 in Figure 2). Low investment cost is one of the causes that leads to the lower cost of these measures. However, for some low-cost measures, the cost estimation results do not include all cost components that should be considered, due to the data gaps (e.g., G09, G10, G13, G49 in Tables 5 & 8). Also, protection measures for specific habitats (G40) or limitations of activities near wind farms (G38) were associated with low costs, which results mainly from the fact that the application areas of the measures are small and no investment costs result from the implementation.

The measures related to marine protected areas (G57, G58) have relatively high costs, which is partly caused by their large areas assumed for the medium scenario of application extent and the approach to estimate the opportunity cost and increasing operational cost from fishery sectors. The application extents in the medium scenario are 7% and 22.5% of the Baltic Sea area for G57 and G58 respectively, which are much

larger than all other extent-based measures. The cost for MSP-related measures (G59) can be divided into several components and only part of the administration cost could be included in the total cost estimate. The operational costs and opportunity costs were not estimated for MSP-related measure and therefore its total cost estimate was identified as not available.

In total, the expected estimated total costs for the proposed new measures are approximately 2 650 million € annually (range: 660-7 200 million €) for the Baltic Sea region when adding up the available costs of the individual measure groups. These values are annualized capital costs plus some operational costs. The range describes the variation in original cost estimates and their uncertainties, and the ranges of the costs for individual measures were calculated based on the minimum and maximum values of relevant collected cost estimates. The ranges and availability of cost estimates is presented in Tables 4-11. In addition, the scopes of some of the original cost estimates used for the analysis were missing which likely lead to cost overlaps between the measures. If these overlaps are considered, the average estimated total cost will be around 2 500 million € annually. The estimated costs and the included cost types of the individual new measure groups are given in Tables 4-11, and the lower and upper bounds of the cost ranges can be seen in Figure 2.

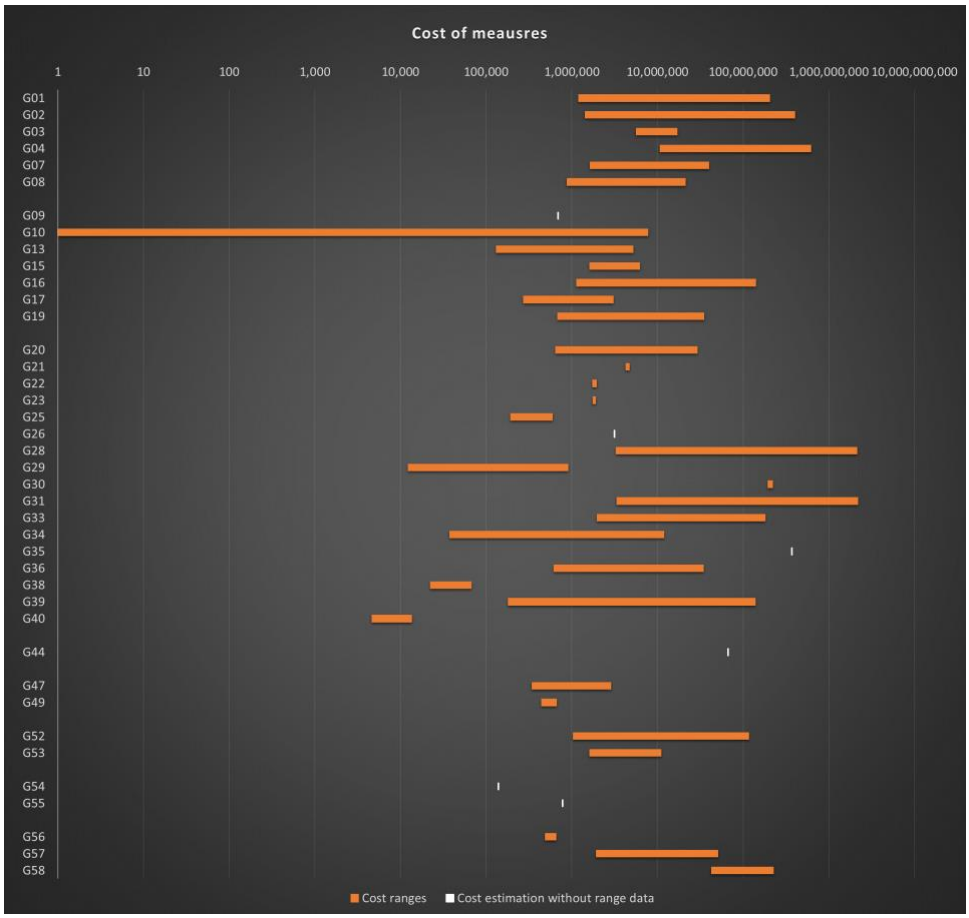

Figure 2. Costs ranges (€/year) of the proposed new measures for the entire Baltic Sea region. Note the logarithmic scale for the cost axis. The names of the measures can be seen in Tables 2-9. The ranges were defined based on the minimum and maximum values of the used cost inputs. The cost database is given in Appendix C.

Table 4. Cost estimation and included cost types of proposed new measures addressing nutrient inputs. Footnotes for the column 'Name' refer to the original HELCOM proposals, some of which were combined due to overlaps.

ID	Name	Total costs[5] (M EUR/year)	If the cost type included in the total cost[6]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G01	Regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea[1]	102 (1-205)	X	X	X	X/NA		
G02	Reduce harmful impact of grey water discharges from Baltic Sea shipping[2]	201 (1-400)	X	X	X	X/NA		
G03	Measures to minimize the discharge of food waste from ships in the Baltic Sea	11 (6-17)	X/NA	X/NA	X	X/NA		
G04	Mussel farming to reduce nutrients at sea[3]	198 (11-618)	X	X				
G05	Reduce nutrient losses to zero from dry bulk fertilizer storage and handling in Baltic ports	NA	X/NA	X/NA	NA	X/NA		YES
G06	Reduce discharges of cargo residues from shipping in the Baltic Sea[4]	NA	X/NA	X/NA	NA	X/NA		
G07	Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies	23 (2-40)	X	X				
G08	Reducing internal phosphorus loads by metal bounding	5 (0.9-21)	X/NA	X				

1) Includes "Actions to further reduce nutrient input of shipping into the Baltic Sea" and "Proposal to regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea".
2) Includes "Actions to reduce harmful impact of grey water discharges from Baltic Sea shipping" and "Proposal to develop a roadmap for managing grey water discharges from ships to reduce nutrient input into the Baltic Sea".
3) Includes "Removal of nutrients from the coastal zone by the use of mussel mitigation cultures" and "Measures related to restoration of coastal habitats – 9. Reducing nutrient loading by farming and harvesting blue mussels".
4) Includes "Develop a HELCOM joint submission to IMO with the intention to recognize nutrients in cargo hold washing water as Harmful for the Marine Environment in the Baltic Sea.", "Limit the discharge of cargo residues from shipping in the Baltic Sea (e.g. vegetable oil and fertilizers)" and "Develop an adequate network of Port Reception Facilities (PRFs) in Baltic ports to receive ship hold washing water".
5) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
6) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
7) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (M EUR/year)

Table 5. Cost estimation and included cost types of proposed new measures addressing fish stocks. Explanations in Table 4.

ID	Name	Total costs[2] (M EUR/year)	If the cost type included in the total cost[4]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G09	A set of 7 measures for coastal fish -5 Seasonal closures	0.7 (NA)[3]	X	-	X	X	NA	-
G10	A set of 7 measures for coastal fish -6 Catch regulations	4 (<0.1-8)	-	-	NA	NA	X/NA	-
G11	Concrete steps to make progress on cooperation between HELCOM and fisheries management (e.g. Baltfish) to improve implementation of BSAP	NA	-	NA	-	-	-	-
G12	Development of alternative fishing gear to replace gillnets	NA	NA	NA	-	-	NA	-
G13	Investigative and trial biomanipulation by removing cyprinids and sticklebacks as a method for rehabilitating coastal ecosystems	3 (0.1-5)	X/NA	X/NA	-	X	-	-
G14	National environmental permitting authorities to take into account possible impacts on weak migratory fish stocks, particularly salmon, as recognized by ICES or nationally, and how this may compromise the ability to reach agreed river specific fish population targets	NA	-	-	-	NA	-	-
G15	Phase out all recreational fishing on eel by 2022	5 (2-6)	-	-	-	NA	X	-
G16	Prioritising mitigation measures in rivers for eel and other fish migration[1]	70 (1-139)	X	X	-	X	X	-
G17	Restocking of marine areas with fry of European Eel (Anguilla anguilla)	2 (0.3-3)	X	X	-	X	-	-
G18	Restore functional populations of Baltic sturgeon by implementing HELCOM Baltic Sea Sturgeon Action Plan	NA	NA	NA	-	NA	NA	-
G19	Restoration of coastal spawning habitats	25 (0.7-35)	X	X	-	X	X	-

1) Includes " Prioritising mitigation measures in rivers for eel and other fish migration" and " Removal of unnecessary dams and migration barriers, especially in small waterways".
2) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
3) Only one source of cost input and the original estimation does not include uncertainty estimation
4) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
5) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (M EUR/year)

Table 6. Cost estimation and included cost types of proposed new measures addressing seabed. Explanations in Table 4.

ID	Name	Total costs[3] (M EUR/year)	If the cost type included in the total cost[6]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G20	Restoration of lost stony reefs[1]	13 (0.6-29)	X	X/NA	-	-	-	-
G21	Speed limits for recreational boating in shallow coastal areas and larger boats near shore	4 (4-5)	X	-	X	X	-	-
G22	Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material	2 (2-2)[4]	X	X	-	X	-	-
G23	Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas	2 (2-2)[4]	X	-	-	X	-	-
G24	Adoption of a moratorium on seabed mining in the Baltic Sea, including a moratium on developing additional permissive regulations and exploitation and exploration contracts.	NA	-	-	-	NA	NA	-
G25	Improved regulation and reporting of small-scale dredging	0,4 (0.2-0.6)	-	-	X	X	-	-
G26	Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea	3 (NA)[5]	X	-	X	X	NA	-
G27	Limit and preclude dredging/extraction near protected areas and increased buffer zones round sensitive areas	NA	-	-	-	NA	NA	-
G28	Restoration of eelgrass, Zostera marina	386 (3-2 134)	X	X	-	X	-	-
G29	Rehabilitation of hypoxic areas by oxygen pumping[2]	0.5 (<0.1-0.9)	X	X	-	-	-	-
G30	Rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage	207 (195-219)	NA	X	-	-	-	-
G31	Restoration of soft bottom macrophytes (other than eelgrass)	488 (3-2 171)	X	X	-	-	-	-

G32	Rehabilitation of hard bottoms by establishment of artificial reefs	NA	NA	NA	-	-	-	-
G33	Restoration of brown macroalgae, mainly Fucus vesiculosus	91 (2-180)	X	X	-	-	-	-
G34	Restoration of blue mussel reefs	6 (<0.1-12)	X	X	-	-	-	-
G35	Restoration of soft bottoms free of vegetation	371 (NA)[5]	NA	X	-	X	-	-
G36	Restoration of coastal wetlands	27 (0.6-34)	X	X	-	X	X	-
G37	Elimination of invasive plant Elodea	NA	NA	NA	-	-	-	-
G38	Areas around windfarms as potential refugia	<0.1 (<0.1-<0.1)	-	X	-	-	X	-
G39	Harvesting of reed and excessive vegetation	96 (0.2-138)	X	X	-	X	-	-
G40	Specific measures to address and protect all biogenic structures	<0.1 (<0.1-<0.1)	-	X	-	-	X	-

1) Includes "Restoration of lost stony reefs" and "Restoration of stony reefs in areas where these have previously been lost".
2) Includes "Rehabilitation of hypoxic areas by oxygen pumping" and "Mixing within deeper water layers to encourage oxygenation at the benthic-pelagic interface".
3) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
4) The range is smaller than 1 M EUR
5) Only one source of cost input and the original estimation does not include uncertainty estimation
6) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
7) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Table 7. Cost estimation and included cost types of proposed new measures addressing hazardous substances. Explanations in Table 4.

ID	Name	Total costs[1] (M EUR/year)	If the cost type included in the total cost[3]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G41	Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory	NA	-	-	NA	NA	NA	-
G42	Safe manure nutrient recycling	NA	NA	NA	-	NA	NA	-
G43	Decreasing the emissions of hazardous substances from small scale emitters in urban areas (municipal entities, businesses and private households) by chemical-smart purchasing strategies, substitution and awareness raising campaigns	NA	-	NA	-	NA	NA	-
G44	Enhance mitigation measures to decrease GHG emissions from shipping- Alternative fuels and sources of energy	66 (NA)[3]	NA	X	-	NA	-	YES
G45	Ban on import and sale of metallic lead in fishing equipment	NA	-	-	NA	NA	-	-

1) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
2) Only one source of cost input and the original estimation does not include uncertainty estimation
3) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
4) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Table 8. Cost estimation and included cost types of proposed new measures addressing litter. Explanations in Table 4.

ID	Name	Total costs[1] (M EUR/year)	If the cost type included in the total cost[2]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G46	Ban (phasing-out) on non-degradable shot wads and information campaigns targeted at hunters	NA	-	-	NA	NA	-	-
G47	Ban on handing out free carrier bags	2 (0.3-3)	-	-	NA	X	-	-
G48	Ban on mass balloon (>50 balloons) releases	NA	-	-	NA	NA	NA	-
G49	Development of a HELCOM guideline on establishment and operation of artificial turfs	0,5 (0.4-0.6)	X	NA	X/NA	X	-	-
G50	Ensure no-special-fee system for marine litter applies to all passive fished waste, as well as all other wastes captured or generated in the Baltic Sea.	NA	NA	NA	-	NA	-	-
G51	Reduction of single-use plastics consumption at major events	NA	NA	NA	NA	NA	-	-

1) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
2) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
3) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Table 9. Cost estimation and included cost types of proposed new measures addressing underwater noise. Explanations in Table 4.

ID	Name	Total costs (M EUR/year)	If the cost type included in the total cost[4]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G52	Reducing continuous underwater noise from shipping and recreational boating[1]	47 (1-116)	X	-	X	X	-	-
G53	Reducing the impact of impulsive underwater sound on marine biodiversity[2]	2 (2-11)	X	X	-	X	-	-

1) Includes "Develop a road map to investigate underwater noise, including possible follow-up actions", "Reducing the impact of continuous underwater sound on marine biodiversity [from shipping]" and "Reducing the impact of continuous underwater sound from recreational boating on marine biodiversity"
2) Includes "Identify and implement Best Available Technique (BAT) and Best Environmental Practice (BEP) to mitigate noise emitting activities" and "Reducing the impact of impulsive underwater sound on marine biodiversity".
3) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
4) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
5) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Table 10. Cost estimation and included cost types of proposed new measures addressing non-indigenous species. Explanations in Table 4.

ID	Name	Total costs[2] (thousand EUR/year)	If the cost type included in the total cost[4]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G54	Adoption and implementation of a HELCOM Roadmap on Biofouling Management[1]	0.1 (NA)[3]	NA	X	-	-	-	YES
G55	Ship's ballast water and sediments management (BWM) by the HELCOM parties' domestic merchant fleets and naval forces as a supplementary measure to control introductions and secondary spread of Harmful Aquatic Organisms and Pathogens (HAOP) in the Baltic Sea.	0.8 (NA)[3]	NA/X	NA/X	-	X	-	-

1) Includes "Adoption and implementation of a HELCOM Roadmap on Biofouling Management" and "Work for the harmonized implementation of the IMO Biofouling Guidelines and Guidance documents, and further work toward the International Biofouling Convention by contributing to the work carried out in the International Maritime Organization (IMO)".
2) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
3) Only one source of cost input and the original estimation does not include uncertainty estimation
4) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
5) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Table 11. Cost estimation and included cost types of proposed new measures addressing harbor porpoise, marine protected areas and maritime spatial planning. Explanations in Table 4.

ID	Name	Total costs[5] (M EUR/year)	If the cost type included in the total cost[6]					If the measure results to cost saving
			Capital costs	O&M costs	Increase in daily business/operation costs	Other financial costs	Opportunity costs	
G56	Mandatory use of pingers[1]	0.6 (0.5-0.7)	X	X	-	NA	-	-
G57	Strict marine protected areas (no use/no take/no entry): Cost related to fishery sector[2]	34 (2-50)	-	-	X	X	X	-
G58	Effectively managed marine protected areas[3]	151 (43-224)	X	X	X	X	X	-
G59	MSP related measures[4]	NA	-	NA	-	X	NA	-

1) Includes "Guidelines and regulation of the design and use of acoustic deterrent devices" and "Mandatory use of Acoustic Deterrent Devices or other effective mitigation measures to minimize bycatch of the Baltic Sea harbour porpoise (Phocoena phocoena)".
2) Incudes "Designate no-use marine protected areas, that also function as scientific reference areas", "Establishment of no-take areas", "Strengthening piscivorous fish to rehabilitate coastal ecosystem function", "No further expansion of fishing effort to areas not already impacted by existing fishing activities" and "Reduction of fishing pressure and development of Good Environmental Status delineation, supported by no go areas to determine benthic species recovery and potentially natural communities".
3) Includes "Establish an effectively and equitably managed, ecologically representative and well-connected system of highly protected marine protected areas (MPAs), covering a minimum of 30 % of the Baltic Sea area by 2030. All MPAs shall include fully closed zones (complying with IUCN 1a category1) or be fully closed in their entirety, depending on the conservation objectives and needs of the specific site", "Protect functionally important ecosystem elements and ecologically significant areas in order to create a regionally coherent network", "Strengthening the management of the Baltic Sea MPA network by introducing key management elements to increase effectiveness of protection", "Enhanced protection of coastal fish habitats" and "Protection of habitats".
4) Includes "Maritime Spatial Planning (MSP) applying an ecosystem-based approach to support BSAP-objectives and targets and contributing to sustainable sea-based activities", "MSP to signal areas of high nature value" and "MSP should steer sea-based activities away from areas where they can cause serious damage or disturbance".
5) In 2020 price level, the average estimation for the medium scenario for Baltic Sea scale. Bracket shows the minimum and maximum value determined by the used cost input.
6) X = costs under this type are included in the total costs; X/NA = only part of the costs under this cost type is included in the total costs; NA=There should be costs under this cost type for this measure, but the cost estimation is not available
7) Colour scale for the average cost: <0,1, 0,1-1, 1-10, 10-100, 100> (thousand EUR/year)

Effectiveness of proposed new measures

The effectiveness of each of the proposed new measures was first estimated as an average reduction of pressures or direct improvement in states for the whole Baltic Sea region (Table 12). The average reduction impacts presented in Table 12 do not give a complete overview of the magnitude of the impacts, because they lack the effects of some measures for which not all or any of the identified effects to reduce pressures from activities could be quantified. Also, measures affecting nutrients from land-based sources are not shown in Table 12. The pressure reduction impact results take into account the contributions of activities to pressures and sum the pressure reductions from different activities. The litter measures and measures targeting land-based nutrient sources are presented and discussed in their own sections. All the presented results are for medium application scenario, but the pressure reduction impacts for other application scenarios are provided in Appendix A. Also, the standard deviations of pressure reduction impacts for all application scenarios are presented in Appendix A.

According to the results, spatial management measures such as marine protected areas and maritime spatial planning may reduce more pressures than other measures (measures G57-59 in Table 12), but this depends on the management plans and the impacts of these measures are always limited to the designated areas. The results also show that the measures closing fishing grounds (measure G09 in Table 12), setting restrictions on fisheries (G10, G15) or protecting spawning grounds (included in G57 and G58) were estimated to significantly reduce several pressures that are related to fish. Further, the measure clearing riverine dams and mitigating their effects on migratory fish may reduce significantly the respective pressures (G16, Table 12). Implementation of this measure may alone significantly improve the conditions of salmon and seatrout stocks.

Many measures that are targeted to specific pressures, such as non-indigenous species (G54-G55), underwater noise (G52-G53), physical loss and disturbance of marine habitats (G21-G27 and G38), or some species-specific pressures, may have significant effects on those pressures only, but they hardly have any effects on other pressures. However, such measures may still be important, especially if they target an activity or pressure which are not managed before (e.g. leakage of fertilizers during port operations, G05), pilot new innovations (e.g. tertiary wastewater treatments with constructed wetlands, G07), or introduce new sectors under the marine policy (e.g. pharmacies, G41). Generally, many measures targeting the major land-based activities, like agriculture or industry, have only limited effectiveness on the specific pressure they are contributing to. However, the overall impact of these measures on total pressures may be considerable, due to the large contributions of these activities to pressures.

Several restoration and rehabilitation measures affect state components directly (such as G28-G37, G17, G18), but their effects were only quantified for restoration of coastal spawning habitats and some fish populations (G19). These are always local measures and, albeit locally effective, their regional influence depends on the number managed of sites.

The findings of the SOM analysis for existing measures suggest that existing measures may not be sufficient in reducing the input of nutrients as indicated by the maximum

allowable inputs (MAI) in the nutrient reduction scheme (HELCOM ACTION 2021h). Thus, new measures targeting nutrients, such as G01-G08, G13, G30 and G39, should be considered for the updated BSAP. However, some of these measures that target sea-based activities for nutrients may not have significant effects compared to measures that target nutrients from land-based sources. The potentially strongest sea-based measures to reduce nutrient inputs are also mainly research oriented (e.g. G02 and G03), and their effectiveness would not be realized during this implementation period.

There are several measures that target marine litter (G46-G51), but their effects to reduce pressures from activities were not quantified in this analysis. This is because of several reasons: estimation of effects and sufficiency would have required disproportionate resources compared to other topics due to different topic structure and features of the analysis that are not currently fully implemented to comply with differences in the topic structures. Also, SOM results suggest that existing measures may be able to reduce top 15 beach litter items by 100%, however this likely due to the fact that some features of the analysis are still incompatible with the topic structure for beach litter.

Table 12. Impacts of measures to reduce pressures presented as Baltic-wide averages for medium application extent scenario. For some measures the impact is not completely estimated due to lack of effectiveness data. These have been marked with an asterisk* in the table. Colour scale for the percent impacts of measures in reducing pressures:
0-10%, 10-20%, 20-40%, 40-60%, 60-100%. The two last columns, coloured with light grey, indicate direct impact of the measures to improve the state of specific benthic habitats or fish species.

Group ID	Measure	Physical disturbance of marine habitats	Physical loss of marine	NIS	Direct pressure to costal	Input of continuous noise 63/125 Hz or 2 kHz	Input of impulsive noise with peak energy below 10 kHz	Input of Litter	Input of nutrients	Input of hazardous	intentional killing of	waterbird bycatch	waterbird disturbance and displacement	marine mammal bycatch	intentional killing of marine mammals	marine mammal disturbance	Targeted extraction and bycatch of fish	Disturbance of fish	Benthic habitats	Fish
G01	Regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea								*											
G02	Reduce harmful impact of grey water discharges from Baltic Sea shipping								*											
G03	Measures to minimize the discharge of food waste from ships in the Baltic Sea								*											
G04	Mussel farming to reduce nutrients at sea[te]																			
G05	Reduce nutrient losses to zero from dry bulk fertilizer storage and handling in Baltic ports								*											
G06	Reduce discharges of cargo residues from shipping in the Baltic Sea								*											
G07	Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies[e]							*		*										
G08	Reducing internal phosphorus loads by metal bounding[e]								*											
G09	A set of 7 measures for coastal fish -5 Seasonal closures																			
G10	A set of 7 measures for coastal fish -6 Catch regulations																			
G11	Concrete steps to make progress on cooperation between HELCOM and fisheries management (e.g. Baltfish) to improve implementation of BSAP																*			
G12	Development of alternative fishing gear to replace gillnets																*			
G13	Investigative and trial biomanipulation by removing cyprinids and sticklebacks as a method for rehabilitating coastal ecosystems[e]								*											
G14	National environmental permitting authorities to take into account possible impacts on weak migratory fish stocks, particularly salmon, as recognized by ICES or nationally, and how this may compromise the ability to reach agreed river specific fish population targets																	*		
G15	Phase out all recreational fishing on eel by 2022																			
G16	Prioritising mitigation measures in rivers for eel and other fish migration[e]																			
G17	Restocking of marine areas with fry of European Eel (Anguilla anguilla)																			*
G18	Restore functional populations of Baltic sturgeon by implementing HELCOM Baltic Sea Sturgeon Action Plan[t]																			*

Group ID	Measure	Physical disturbance of marine habitats	Physical loss of marine	NIS	Direct pressure to costal	Input of continuous noise 63/125 Hz or 2 kHz	Input of impulsive noise with peak energy below 10 kHz	Input of Litter	Input of nutrients	Input of hazardous	intentional killing of	waterbird bycatch	waterbird disturbance and displacement	marine mammal bycatch	intentional killing of marine mammals	marine mammal disturbance	Targeted extraction and bycatch of fish	Disturbance of fish	Benthic habitats	Fish
G19	Restoration of coastal spawning habitats[e]																			
G20	Restoration of lost stony reefs[ŧe]																			
G21	Speed limits for recreational boating in shallow coastal areas and larger boats near shore																			
G22	Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material[e]																			
G23	Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas																			
G24	Adoption of a moratorium on seabed mining in the Baltic Sea, including a moratium on developing additional permissive regulations and exploitation and exploration contracts.	*	*																	
G25	Improved regulation and reporting of small-scale dredging																			
G26	Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea	*	*																	
G27	Limit and preclude dredging/extraction near protected areas and increased buffer zones round sensitive areas																			
G28	Restoration of eelgrass, Zostera marina[ŧe]																		*	
G29	Rehabilitation of hypoxic areas by oxygen pumping[e]																		*	
G30	Rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage[e]								*	*										
G31	Restoration of soft bottom macrophytes (other than eelgrass)[e]																		*	
G32	Rehabilitation of hard bottoms by establishment of artificial reefs[e]																		*	
G33	Restoration of brown macroalgae, mainly Fucus vesiculosus[ŧe]																		*	
G34	Restoration of blue mussel reefs[ŧe]																		*	
G35	Restoration of soft bottoms free of vegetation[e]																		*	
G37	Elimination of invasive plant Elodea[e]																		*	
G38	Areas around windfarms as potential refugia[e]																			
G39	Harvesting of reed and excessive vegetation[ŧe]																			
G36	Restoration of coastal wetlands[e]																			
G40	Specific measures to address and protect all biogenic structures[e]																		*	

Group ID	Measure	Physical disturbance of marine habitats	Physical loss of marine	NIS	Direct pressure to costal	Input of continuous noise 63/125 Hz or 2 kHz	Input of impulsive noise with peak energy below 10 kHz	Input of Litter	Input of nutrients	Input of hazardous	intentional killing of	waterbird bycatch	waterbird disturbance and displacement	marine mammal bycatch	intentional killing of marine mammals	marine mammal disturbance	Targeted extraction and bycatch of fish	Disturbance of fish	Benthic habitats	Fish
G41	Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory																			
G42	Safe manure nutrient recycling																			
G43	Decreasing the emissions of hazardous substances from small scale emitters in urban areas (municipal entities, businesses and private households) by chemical-smart purchasing strategies, substitution and awareness raising campaigns									*										
G44	Enhance mitigation measures to decrease GHG emissions from shipping- Alternative fuels and sources of energy																			
G45	Ban on import and sale of metallic lead in fishing equipment									*										
G46	Ban (phasing-out) on non-degradable shot wads and information campaigns targeted at hunters							*												
G47	Ban on handing out free carrier bags							*												
G48	Ban on mass balloon (>50 ballons) releases							*												
G49	Development of a HELCOM guideline on establishment and operation of artificial turfs							*												
G50	Ensure no-special-fee system for marine litter applies to all passive fished waste, as well as all other wastes captured or generated in the Baltic Sea.							*												
G51	Reduction of single-use plastics consumption at major events							*												
G52	Reducing continuous underwater noise from shipping and recreational boating																			
G53	Reducing the impact of impulsive underwater sound on marine biodiversity						*													
G54	Adoption and implementation of a HELCOM Roadmap on Biofouling Management																			
G55	Ship's ballast water and sediments management (BWM) by the HELCOM parties' domestic merchant fleets and naval forces as a supplementary measure to control introductions and secondary spread of Harmful Aquatic Organisms and Pathogens (HAOP) in the Baltic Sea.																			
G56	Mandatory use of pingers[ł]																			
G57	Strict marine protected areas (no use/no take/no entry) [łe]																			
G58	Effectively managed marine protected areas[e]																			
G59	MSP related measures																			

[ł]Not assumed to be applied in all basins, [e]Application extent differs between medium, minimum and maximum.

Cost-effectiveness of proposed new measures

Table 13 shows the effectiveness of the individual proposed new measures in closing the gap between the expected total pressure reduction resulting from existing measures and expected total pressure reduction required for good state or improvement in state[7]. Table 14 shows the effectiveness of individual new measures in reducing the total pressures with respect to different state components in "absolute" percentage terms (i.e. not relative to the GAP, see Figure 1). The relative presentation has been used in previous analyses on cost-effectiveness of MSFD measures (Kontogianni et al., 2015; Oinonen et al. 2016), but measure-activity-pressure-state approach used in the SOM analysis allows the assessment of impacts in more absolute terms. Here the results of both the approaches are presented to highlight their ramifications on the results and possible policy implications. Figure 3 shows the identified linkages between the proposed new measures, reduced inputs of pressures, pressures affecting state and assessed state components. These were defined based on the data used for the SOM analysis on existing measures and the effectiveness data for new measures. The myriad of components and linkages between them indicate that the environmental state of the Baltic Sea is a complex issue. The red lines between components denote identified linkages that were not quantified in the analysis due to lack of data or limited resources.

The pressures included in the total pressure reductions are those for which a decrease in the input of pressure resulting from a measure has an equal impact on the impact of pressure on the state component, and these pressures may vary by state component. For new measures and assessed state components these pressures include physical disturbance and loss of marine habitats; targeted extraction and bycatch of coastal fish, flatfish and seatrout; disturbance of species: obstructions and collisions; and input of PFOS, mercury and diclofenac[8]. Only new measures affecting these pressures are included in Tables 13 and 14. The input pressure reductions for pressures that do not result in reduction of equal magnitude in pressures affecting state (input of non-indigenous species and input of hazardous substances) but for which a link between the input of pressure and pressure affecting state is identified are provided in Appendix D and they are also presented as red links between reduced input pressure and pressure affecting State in Figure 3. Such pressures also include input of nutrients which are out of scope of the results presented in Table 13 due to lack of quantified measure effects on pressures from activities.

According to the SOM topic reports, most of the state components are affected by impacts of eutrophication and, as concluded in the topic specific SOM report for nutrients, existing measures may not be sufficient in reducing the input of nutrients as indicated by the maximum allowable inputs (MAI) in the nutrient reduction scheme. Also changes in hydrologic conditions and changes in human induced food web imbalance were identified as significant pressures for several state components, but according to the effectiveness data used for the analyses of existing and new measures

[7] If state improvement is defined as 10%, 25% and 50% improvement in state, the average of the expected required pressure reduction is used.

[8] The reduction in the pressure affecting state for hazardous substances is of equal magnitude than the reduced pressure only for the given state component. (e.g. reduction of mercury input and impact of heavy metal pollution are of equal quantity only for mercury concentration)

they are not affected by any of the existing or new measures (Figure 3). Further, effects of non-indigenous species and hazardous substances were also identified as significant pressures for not achieving good state for multiple state components, but for most state components the reductions in their inputs could not be directly linked to the effects of these pressures on the state component (Figure 3). Therefore, these are also not accounted for in the impact values of Tables 13 and 14. Since the above-mentioned pressures are significant drivers for the undesired environmental state of many state components, it can be concluded that measures targeting nutrient inputs, hazardous substances, NIS, hydrological conditions and food webs could possibly be considered to be implemented in the updated BSAP. However, the need for new measures targeting these pressures depends on the impacts of existing measures, which for most parts could not be assessed with respect to impacts of input pressure reductions on state components.

The results of Table 13 and 14 takes into account the effectiveness of measures in reducing pressures from activities, contributions of pressures from activities, and the significance of different pressures to state components. Results of Table 13 further integrate the pressure reductions resulting from existing measures and pressure reductions required for good state or state improvement into the relative impacts. Total impact value calculated as a sum of topic specific averages defines the total impact on all assessed topics (benthic habitats, hazardous substances and fish). State components of other topics were either already in good state or according to the SOM analysis on existing measures lacked sufficient expert data to establish a connection between reduction in pressures and improvement in state. The costs impact ratios were finally calculated by dividing the expected costs of measures by the total impact, meaning that lower cost-impact ratios imply better cost-effectiveness. The impacts and cost-impact ratios presented in Table 13 and 14 should only be considered for the covered state components and pressures.

The results of Table 13 on relative impacts indicate that the effectively protected marine areas (G58) and MSP measures (G59) have most significant impacts on closing the gap in total pressure with respect to assessed state components and pressures. However, the costs of marine protected area measures may be high, and thus the cost impact ratio indicates that these measures may not be most cost effective. The cost data to assess costs of MSP measures were insufficient. Seasonal closures of coastal fisheries (G09) and measures to limit the impacts of dredging, sediment extraction and other bottom disturbing activities (G26) were also found effective. These measures were also found relatively cost-effective, especially seasonal closures of costal fisheries. Other most cost-effective measures according to Table 13 are areas around windfarms as potential refugia (G38) and the two regulatory measures for smaller vessels in sensitive and shallow coastal areas (G21 and G23). The cost effectiveness of the former is driven especially by the low costs, while the regulations of boating, by adding speed limits (G21) or limiting boating to established routes (G23), were seen to reduce total pressures for several state components.

It should be noted that the impact values of Table 13 describe how much the measure reduces the total pressure in relation to remaining gap after existing measures. In that sense, if pressure reduction is already close to the required pressure reduction, even a small reduction in total pressure might generate a large impact value. Also, a large

reduction in total pressure from a measure may not appear as a high impact value if the gap to the required state is wider. Therefore, the results should be compared with Table 14. The results of Table 14 for absolute total pressure reductions are mostly in line with the relative impacts. However, the order of measures based on cost impact ratios changes significantly for strict marine protected areas (G57, -3 in the ranking of measures) and prioritizing the use of constructed wetlands (G07,+2 in the ranking of measures). This indicates that G57 reduces total pressures for state components that after the full effect of existing measures are already relatively closer good state, whereas G07 reduces pressures for those state components that are relatively further away from good state. For measures G21, G25 and G22 the ranking changes by one (+1,-1 and +1 respectively). Absolute total pressure reductions could further be translated to increases in probabilities to reach good state for state components, but since the relationship between total pressure reduction and probability to reach good state is nonlinear, the impacts of measures are not additive, and such transformation would require assumptions on the implementation of other new measures. In other words, the impact that an individual measure has on the probability to reach good state depends on the implementation of other measures.

However, several perspectives should be carefully considered when using the impact and cost impact ratios presented in Tables 13 and 14. As previously stated, the impacts and cost-impact ratios presented in Table 13 should only be considered for the covered state components and pressures. In addition to this, some low-cost measures (e.g. protection of biogenic structures, G40) do not have effectiveness results available, and some high-effectiveness measures (e.g. maritime spatial planning, G59) lack cost information. Also, the incomplete cost estimation for some measures with low cost-impact ratio (e.g., G09, G26, G10) should be further taken into account when interpreting the results. Regardless of all the limitations, Tables 13 and 14 provide methods to compare the effects/sufficiency and costs of the proposed new measures.

The results of Tables 12, 13 and 14 do not show the overlaps among measures, i.e. if they affect the pressures from the same activities. These overlaps refer to the overlaps defined by chain impacts in the SOM analysis and they are not to be mixed with thematic overlaps used for grouping the new measures. Thematic overlaps define if two measures are actually the same measure and overlaps discussed in this section cover overlaps that emerge if multiple measures affect same pressures from same activities. A cross tabulation table for new measures with respect to activities and pressures (Table 15) shows overlaps of measures with respect to all identified activity-pressure pairs.

Therefore, pressures for which the linkage between the reduced pressure input and the pressure affecting state could be identified are included in Table 15, but there was no requirement that these linkages were quantified (see lines in Figure 3). These pressures include the same pressures as the pressures taken into account in Tables 13 and 14 as well as nutrient inputs from marine sources, introduction of NIS, hazardous substances and input of litter. The number in each cell of the table shows how many of the same pressures from the same activities do the measures affect. If two measures overlap by reducing many same pressures from same activities, it might not be a feasible solution to implement both of these measures. Most of the new measures are assumed to be implemented for the whole Baltic Sea and thus the overlaps generally apply for the entire Baltic Sea region (see Appendix B for exceptions). The overlaps of new measures

with existing measures are also presented in Table 15, where existing measures are treated as one measure. For existing measures there are more measures that are implemented only in some areas of the Baltic Sea and thus not all of the overlaps with existing measures apply for the entire Baltic Sea region. Also overlaps concerning litter and nutrient inputs are not included in the overlaps with existing measures. The overlap with the measure itself shows how many different activity pressure contributions does the measure target.

Table 15 generally shows overlaps for measures intended to target the same pressures. For example, the nutrient input reduction measures G01-G03 and G06 overlap with each other by targeting nutrient inputs from ships, whereas nutrient input reduction measure G05 *Reduce nutrient losses to zero from dry bulk fertilizer storage and handling in Baltic ports* do not have overlapping measures. The new measures that have most overlaps with existing and other measures are MSP and MPA measures that overlap with many measures targeting single pressures and with other MSP and MPA measures that reduce pressures from multiple activities. The other new measures that have most overlaps with other new measures and existing measures are fishing related measures G11 and G12, measure related to dredging and seabed G22, G24-G27 as well as noise related measures G52 and G53. The amount of overlaps for these measures may stem from that they target pressures that are mainly caused by only few human activities. Therefore, the number of optional activities through which to reduce these pressures is lower than for pressures that result from multitude of activities.

Table 13. Relative impacts and costs of proposed new measures. Impacts show the ability of measures to bridge the gap to GES/improvement in state after considering the effects of existing measures (i.e. impacts of measures in closing the gap between the expected pressure reductions resulting from existing measures and expected total pressure reductions required for good/Improvement in state). Colour scale for the percentage impact that the measure has on closing the gap: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%

Group IDs	**Measure**	Hard substrate vegetation dominated community	Soft substrate vegetation dominated community	Hard substrate epifauna dominated community	Soft substrate infauna dominated community	Coarse substrate infauna dominated community	Mercury concentration	TBT concentration	PFOS concentration	Diclofenac concentration	**Birds**	**Mammals**	Salmon AU	Eel	Seatrout	Perch and other coastal piscivores	Cyprinids and other mesopredators	Flounder	Herring	Cod	Sprat	Plaice	Expected total impact (%)	Expected cost (milj.€)	Cost-Impact ratio
G09	A set of 7 measures for coastal fish -5 Seasonal closures																						14.1	0.7	4.9
G38	Areas around windfarms as potential refugia																						0.5	0.05	9.3
G23	Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas																						7.2	1.8	25.3
G26	Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea																						11.6	3.1	26.9
G10	A set of 7 measures for coastal fish -6 Catch regulations																						7.3	3.9	53.0
G25	Improved regulation and reporting of small-scale dredging																						0.7	0.4	54.7
G21	Speed limits for recreational boating in shallow coastal areas and larger boats near shore																						7.1	4.5	63.0
G57	Strict marine protected areas (no use/no take/no entry): Cost related to fishery sector																						9.1	33.9	371.5
G22	Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material																						0.5	1.9	396.2
G58	Effectively managed marine protected areas																						26.2	151	576.1
G07	Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies																						3.1	22.9	737.2
G16	Removal of unnecessary dams and migration barriers, especially in small waterways																						3.9	70.3	1785.3
G41	Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory																						1.2	NA	-
G42	Safe manure nutrient recycling																						0.2	NA	-
G27	Limit and preclude dredging/extraction near protected areas and increased buffer zones round sensitive areas																						3.2	NA	-
G59	MSP related measures																						48.2	NA	-

Table 14. "Absolute" impacts and costs of proposed new measures. Impacts are defined as total pressure reductions for state components. Colour scale for the percentage impact that the measure has on reducing the pressure: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%

Group IDs	Measure	Hard substrate vegetation dominated community	Soft substrate vegetation dominated community	Hard substrate epifauna dominated community	Soft substrate infauna dominated community	Coarse substrate infauna dominated community	Mercury concentration	TBT concentration	PFOS concentration	Diclofenac concentration	Birds	Mammals	Salmon AU	Eel	Seatrout	Perch and other coastal piscivores	Cyprinids and other mesopredators	Flounder	Herring	Cod	Sprat	Plaice	Expected total reduction (%)	Expected cost (milj.€)	Cost-Impact - ratio with expected total reduction
G09	A set of 7 measures for coastal fish -5 Seasonal closures																						5.5	0.7	12.5
G38	Areas around windfarms as potential refugia																						0.1	0.05	32.1
G23	Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas																						2.9	1.8	63.0
G26	Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea																						3.1	3.1	100.8
G10	A set of 7 measures for coastal fish -6 Catch regulations																						2.8	3.9	137.6
G21	Speed limits for recreational boating in shallow coastal areas and larger boats near shore																						2.9	4.5	155.1
G25	Improved regulation and reporting of small-scale dredging																						0.3	0.4	156.8
G22	Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material																						0.2	1.9	1154.4
G07	Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies																						1.8	22.9	1270.7
G58	Effectively managed marine protected areas																						7.7	151	1961.6
G57	Strict marine protected areas (no use/no take/no entry): Cost related to fishery sector																						1.5	33.9	2258.0
G16	Removal of unnecessary dams and migration barriers, especially in small waterways																						1.6	70.3	4391.8
G59	MSP related measures																						14.2	NA	-
G27	Limit and preclude dredging/extraction near protected areas and increased buffer zones round sensitive areas																						0.8	NA	-
G41	Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory																						0.7	NA	-
G42	Safe manure nutrient recycling																						0.1	NA	-
All	Remaining GAP after existing measures (%)	36.5	26.7	29.4	32.6	20.4		70.7	43.1	57.1				60.4	42.6	21.9	28.6	37.3	35.5		60.1		127.0		

Table 15. Cross-tabulation of measures with respect to activity pressure pairs (which pressures do measures target from which activities) to show the overlaps of measures.

Group		G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G16	G21	G22	G23	G24	G25	G26	G27	G30	G38	G39	G41	G42	G43	G45	G46	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	Existing measures
G01	Regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea	2	2	2			2																																					
G02	Reduce harmful impact of grey water discharges from Baltic Sea shipping	2	2	2			2																																					
G03	Measures to minimize the discharge of food waste from ships in the Baltic Sea	2	2	2			2																																					
G04	Mussel farming to reduce nutrients at sea				2				1					2										1		2																		
G05	Reduce nutrient losses to zero from dry bulk fertilizer storage and handling in Baltic ports					2																																						
G06	Reduce discharges of cargo residues from shipping in the Baltic Sea	2	2	2			2																																					
G07	Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies							10																			1																3
G08	Reducing internal phosphorus loads by metal bounding				1				1					1										1		1																		
G09	A set of 7 measures for coastal fish -5 Seasonal closures									1	1	1	1																												1	1		1
G10	A set of 7 measures for coastal fish -6 Catch regulations									1	1	1	1																												1	1		1
G11	Concrete steps to make progress on cooperation between HELCOM and fisheries management (e.g. Baltfish) to improve implementation of BSAP									1	1	3	3																												3	3		3
G12	Development of alternative fishing gear to replace gillnets									1	1	3	3																												3	3		3

Group		G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G16	G21	G22	G23	G24	G25	G26	G27	G30	G38	G39	G41	G42	G43	G45	G46	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	Existing measures
G13	Investigative and trial biomanipulation by removing cyprinids and sticklebacks as a method for rehabilitating coastal ecosystems				2				1					2										1		2																	
G14	National environmental permitting authorities to take into account possible impacts on weak migratory fish stocks, particularly salmon, as recognized by ICES or nationally, and how this may compromise the ability to reach agreed river specific fish population targets														1	1																												1
G16	Prioritising mitigation measures in rivers for eel and other fish migration														1	1																												1
G21	Speed limits for recreational boating in shallow coastal areas and larger boats near shore																1		1			1																				1	1	1	1
G22	Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material																	2		1	1	2	2																		2	2	2	2
G23	Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas																1		1			1																			1	1	1	1
G24	Adoption of a moratorium on seabed mining in the Baltic Sea, including a moratium on developing additional permissive regulations and exploitation and exploration contracts.																	1		2		2	2																		2	2	2	2
G25	Improved regulation and reporting of small-scale dredging																	1			2	2	2																		2	2	2	2

Group		G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G16	G21	G22	G23	G24	G25	G26	G27	G30	G38	G39	G41	G42	G43	G45	G46	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	Existing measures
G26	Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea																1	2	1	2	2	6	4																		5	6	6	6
G27	Limit and preclude dredging/extraction near protected areas and increased buffer zones round sensitive areas																	2		2	2	4	4																			4	4	4	4
G30	Rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage				1				1					1										4		1			2															
G38	Areas around windfarms as potential refugia																								2																	1	1	2	2
G39	Harvesting of reed and excessive vegetation				2				1					2										1		2																			
G41	Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory							1																			1																	1
G42	Safe manure nutrient recycling																											2																
G43	Decreasing the emissions of hazardous substances from small scale emitters in urban areas (municipal entities, businesses and private households) by chemical-smart purchasing strategies, substitution and awareness raising campaigns																							2					2															
G45	Ban on import and sale of metallic lead in fishing equipment																													1														
G46	Ban (phasing-out) on non-degradable shot wads and information																														1													

Group		G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G16	G21	G22	G23	G24	G25	G26	G27	G30	G38	G39	G41	G42	G43	G45	G46	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	Existing measures
	campaigns targeted at hunters																																											
G47	Ban on handing out free carrier bags																														1	1		1	1									
G48	Ban on mass balloon (>50 ballons) releases																														1	1		1	1									
G49	Development of a HELCOM guideline on establishment and operation of artificial turfs																																1											
G50	Ensure no-special-fee system for marine litter applies to all passive fished waste, as well as all other wastes captured or generated in the Baltic Sea.																														1	1		4	4									
G51	Reduction of single-use plastics consumption at major events																														1	1		4	4									
G52	Reducing continuous underwater noise from shipping and recreational boating																																			4	4				4	4		4
G53	Reducing the impact of impulsive underwater sound on marine biodiversity																																			4	11				4	4		11
G54	Adoption and implementation of a HELCOM Roadmap on Biofouling Management																																					1						
G55	Ship's ballast water and sediments management (BWM) by the HELCOM parties' domestic merchant fleets and naval forces as a supplementary measure to control introductions and secondary spread of Harmful Aquatic Organisms and Pathogens (HAOP) in the Baltic Sea.																																						1					1
G56	Mandatory use of pingers																																							1	1	1		1

Group		G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G16	G21	G22	G23	G24	G25	G26	G27	G30	G38	G39	G41	G42	G43	G45	G46	G47	G48	G49	G50	G51	G52	G53	G54	G55	G56	G57	G58	G59	Existing measures
G57	Strict marine protected areas (no use/no take/no entry)									1	1	3	3				1	2	1	2	2	5	4		1												4	4			1	32	32	8	19
G58	Effectively managed marine protected areas									1	1	3	3				1	2	1	2	2	6	4		1												4	4			1	32	42	10	21
G59	MSP related measures																1	2	1	2	2	6	4		2																	8	10	16	16
	Existing measures							3		1	1	3	3		1	1	1	2	1	2	2	6	4		2		1									4	11		1	1	19	21	16	46

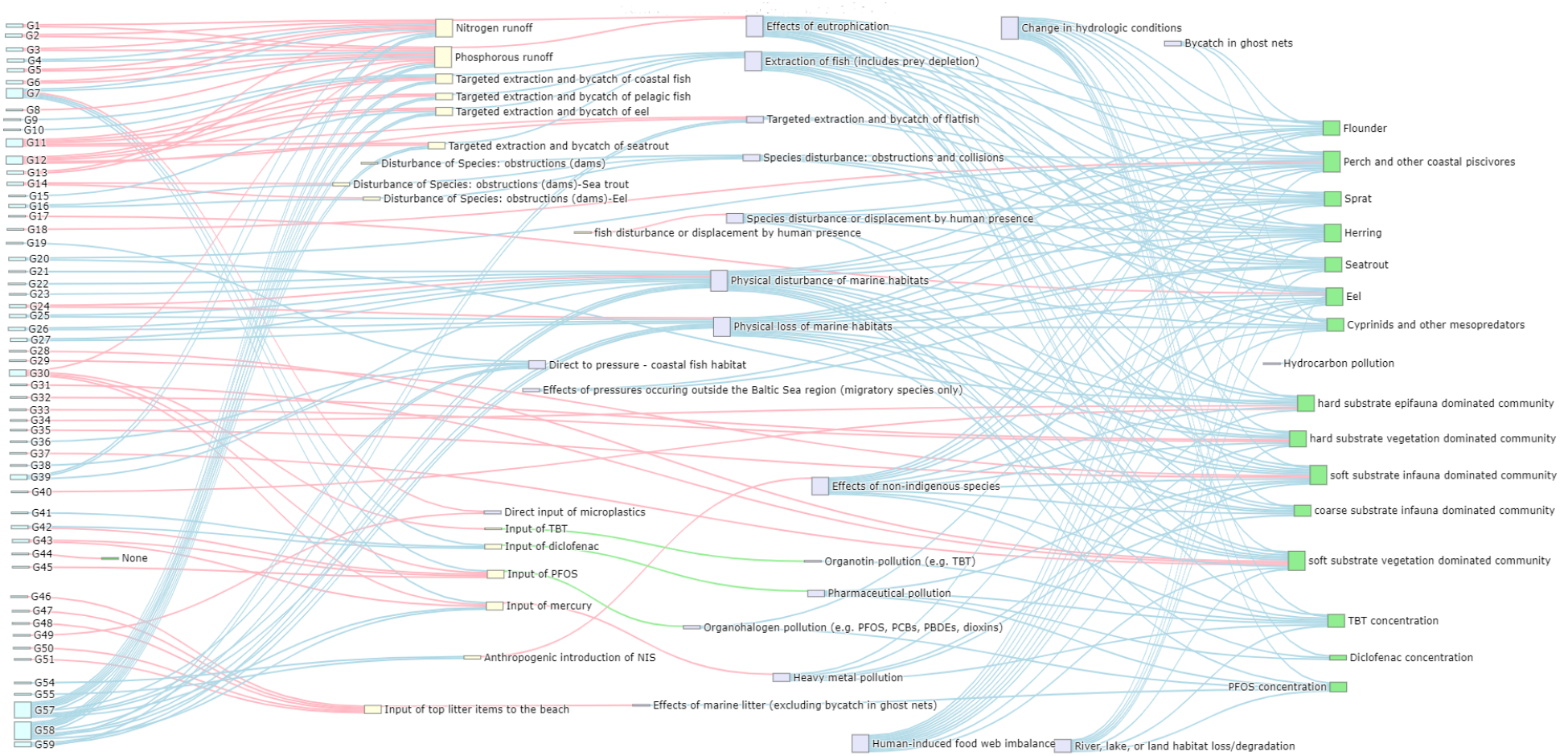

Figure 3. Identified linkages between new measures (left, light cyan), reduced inputs of pressure (left center, yellow), pressures affecting state (right center, lavender) and state components (right, green). Blue line denotes a quantified link between two components, red line an unquantified but identified link, and green partly quantified link between reduced pressure and pressure effecting state (with respect to only some state components).

Proposed new measures for litter and land-based nutrients

Seven new measures addressing the input of microplastics and litter were proposed (Table 16). The majority of these measures address input of litter from land-based activities, such as waste waters and solid waste, but also measures targeting fishing, shipping and tourism are included. Direct input of microplastics is covered by two new measures addressing urban use and waste waters. The reductions in pressures caused by measures targeting litter are identified in Table 16 but their quantity is not assessed due to differences in topic structure compared to other topics.

A total of 18 new measures have been proposed for land-based inputs of nutrients (Table 17). Only one measure, strengthening existing HELCOM Recommendation on municipal wastewater treatment, tackles the nutrient inputs from other activities than from agriculture. The rest of the 17 measures are directly related to agriculture. However, the measure for constructed wetlands reduces nutrients also from other land use practices, such as forestry and urban areas (i.e. stormwaters). The land-based nutrient measures were otherwise not included in this analysis due to lack of time and resources. Also, more sophisticated and comprehensive analyses methods already exist and methods on the matter than what could be achieved with the current SOM approach for cost-effectiveness analysis (see for example Pihlainen et al. 2020, Hyytiäinen et al. 2015, Nainggolan et al. 2018, Hasler et al. 2019). In previous sections it has been concluded that new measures targeting nutrient loading are likely needed. Since the linkage between the input of nutrients and eutrophication affecting state was not quantified in the analysis, inclusion of land based nutrient measures would not change the results with respect to sufficiency of measures to reach good state. However, the measures targeting land-based nutrients would likely be effective in reducing the total input of nutrients, because land-based activities such as agriculture are significant sources of total nutrient inputs.

Table 16. New proposed measures for input of microplastics and litter

Measure	Activity	Pressure
Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies	Urban uses (land use), including storm water runoff	Direct input of microplastics
	Waste water treatment	
Ban (phasing-out) on non-degradable shot wads and information campaigns targeted at hunters	Hunting and population control	Plastic and polystyrene pieces 0-50 cm
Ban on handing out free carrier bags	Land based Activities (Urban use, Waste water)	Plastic bags of different size and color
Ban on mass balloon (>50 ballons) releases	Land based Activities (Urban use, Waste water)	Industrial packaging, such as sheeting and strapping bands
Development of a HELCOM guideline on establishment and operation of artificial turfs	Land based Activities (Urban use, Waste water)	Direct input of microplastics
Ensure no-special-fee system for marine litter applies to all passive fished waste, as well as all other wastes captured or generated in the Baltic Sea.	Transport – shipping (incl. anchoring, mooring)	String and ropes of different size
	Fish and shellfish harvesting (all gears; professional, recreational)	
	Tourism and leisure activities (boating, beach use, water sports, etc.)	
	Land based Activities (Urban use, Waste water)	
Reduction of single-use plastics consumption at major events	Fish and shellfish harvesting (all gears; professional, recreational)	Food related items, such as containers, lolly sticks, wrappers, packets
		Drinking related items such as cups, caps, lids, six-pack rings
		Plastic bags of different size and color
		Bottles and containers
		Single-use cutlery and straws
	Tourism and leisure activities (boating, beach use, water sports, etc.)	Food related items, such as containers, lolly sticks, wrappers, packets
		Drinking related items such as cups, caps, lids, six-pack rings
		Plastic bags of different size and color
		Bottles and containers
		Single-use cutlery and straws
	Transport – shipping (incl. anchoring, mooring)	Food related items, such as containers, lolly sticks, wrappers, packets
		Drinking related items such as cups, caps, lids, six-pack rings
		Plastic bags of different size and color
		Bottles and containers
		Single-use cutlery and straws
	Land based Activities (Urban use, Waste water)	Food related items, such as containers, lolly sticks, wrappers, packets
		Drinking related items such as cups, caps, lids, six-pack rings
		Plastic bags of different size and color
		Bottles and containers
		Single-use cutlery and straws

Table 17. New measures for land-based input of nutrients

Measure	Activity
Adapted buffer zones to reduce phosphorus losses from agricultural land, for example on parts of fields where surface runoff and erosion occurs, along ditches or at surface water inlets	Agriculture
Adapted fertilization rate and precision fertilization in order to increase nitrogen efficiency and reduce nitrogen losses	
Annual field-level fertilization planning and farm-gate nutrient balancing for nitrogen (N) and phosphorus (P) should be a requirement for all farms in the Baltic Sea Region	
Develop recommendations to support national strategies for manure management in the BSR specifically from horses, sheep, goats, and fur farming	
Improve soil structure and aggregate stability on clay soils to reduce phosphorus losses from agricultural lands, for example by using soil structure lime or gypsum	
Incentives to support the use and the production of manure based recycled nutrients	
Increase organic farming to reduce the inputs of nutrients and hazardous substances to the Baltic Sea	
Levy on mineral phosphorus in animal fodder and on mineral fertilizer P	
Levy on nitrogen in mineral fertilizer	
Nutrient-balanced fertilization to control nutrient surplus on farmland	
Prohibition of post harvest application of manure and other organic fertilizers	
Promote regenerative farming practises for multiple benefits	
Recycling of nutrients and carbon in agricultural residues by use of anaerobic digestion	
Reducing livestock densities and coupling livestock to the area of available farmland	
Use of gypsum to reduce phosphorus loads from agricultural land	
Develop incentives to promote applying slow- and controlled-release fertilisers (SRF/CRF)	
Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies	Agriculture Forestry
Strengthening of HELCOM Recommendation 28E/5 on MUNICIPAL WASTEWATER TREATMENT	Waste water treatment

4. Sufficiency of existing and proposed new measures

Reductions of pressures by the proposed new measures

According to the SOM analysis, the proposed new measures result in significant further pressure reductions on top of the reductions from the existing measures (Table 18). The results are presented for each sub-basin, but they were assessed for the same pressure specific assessment units consisting of one or multiple sub-basins as in the SOM analysis for existing measures. All the presented results are for medium application scenario, but the projected pressure reductions for other application scenarios are provided in Appendix A. Also, the standard deviations of projected pressure reductions for all application scenarios are presented in Appendix A. The results for projected pressure reductions and improvements in state are estimated for human activity development scenario that takes into account most likely changes in human activities contributing to pressures (see SOM methodology report).

The projected reductions in physical loss and physical disturbance of seabed are significant especially when compared with the reductions in other pressures. This stems from the abundance of new measures affecting seabed related pressures and also from their estimated high effectiveness. The same applies to most of the fishing related pressures. The projected reductions in physical loss and disturbance of seabed, and in targeted extraction, by-catch and disturbance of fish could be even higher if all measure effects were quantified, but due to the gaps in available effectiveness data, the impacts of two seabed related measures[9] (G24 and G26) and three fishing related measures[10] (G11, G12 and G14) are not completely represented in the results. For all measure impacts and data gaps related to them, see Table 12.

According to the results for hazardous substances, the inputs of pressures are only reduced for mercury and diclofenac whereas inputs of TBT and PFOS are not affected by the new measures. However, it has to be noted that the projected pressure reductions for hazardous substances only include full effects from four measures of all eight new measures and thus the impacts of the other four measures[11] (G07, G30, G40 and G45) are not fully included in the results.

The projected pressure reductions for underwater noise are significant for both continuous and impulsive noise, and all measure effects affecting noise were quantified

[9] G24: Adoption of a moratorium on seabed mining in the Baltic Sea, including a moratium on developing additional permissive regulations and exploitation and exploration contracts; G26: Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea

[10] G11: Concrete steps to make progress on cooperation between HELCOM and fisheries management (e.g. Baltfish) to improve implementation of BSAP; G12: Development of alternative fishing gear to replace gillnets; G14: National environmental permitting authorities to take into account possible impacts on weak migratory fish stocks, particularly salmon, as recognized by ICES or nationally, and how this may compromise the ability to reach agreed river specific fish population targets

[11] G07:Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies; G30: Rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage; G40: Specific measures to address and protect all biogenic structures;G45: Ban on import and sale of metallic lead in fishing equipment

except for measure[12] G53 which effects could be only partially included. The results further show that the implementation of the new measures can lead to reductions in introductions of non-indigenous species (NIS). For NIS measures there were no missing measure effectiveness estimates.

The measure effects for nutrients were for the most parts not quantified or they affected nutrients from human activities that were considered as insignificant contributors to nutrient loading. Six new measures were estimated to reduce nutrient inputs from shipping and port activities and three other new measures would harvest or remove nutrients from the sea[13]. Also, the measures targeting nutrients in catchment areas were not included in the analysis due to the lack of additional resources required to include this data in the analysis. Additional 16 new measures were proposed to the catchment areas to reduce nutrient inputs (Table 17). Further, the effects of measures affecting macro or micro litter were not assessed in the analysis[14].

Finally, the projected reductions in all other pressures presented in Table 18 (bycatches, targeted extractions, disturbances, and intentional killings of different species) result solely from the measures G57-G59 related to marine protected areas and marine spatial planning except the reduction in the by-catch of harbor porpoise which is also affected by the measure G56 on mandatory use of pingers.

[12] G53: Reducing the impact of impulsive underwater sound on marine biodiversity
[13] G01-G08, G13 (See Table 12)
[14] G46-G51 (See Table 12)

Table 18. Pressure reductions by the existing measures ('E') and the existing and proposed new measures ('E+N'). The effect of new measures is seen in the change of the colour. Colour scale for the percent reduction in pressures: 0%, >0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

	Kattegat		Great Belt		The Sound		Kiel Bay		Bay of Mecklenburg		Arkona Basin		Bornholm Basin		Gdansk Basin		E. Gotland Basin		W. Gotland Basin		Gulf of Riga		Northern Baltic Proper		Gulf of Finland		Åland Sea		Bothnian Sea		The Quark		Bothnian Bay	
	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	E	E+N
Physical disturbance																																
Physical loss																																
Introductions of non-indigenous species (NIS)																																
Pressures to coastal fish habitats																																
Continuous noise 63/125 Hz																																
Continuous noise 2 kHz																																
Impulsive noise																																
Nitrogen inputs																																
Phosphorus inputs																																
Bycatch of seabirds																																
Bycatch of harbour porpoise																															NA	NA
Bycatch of seals																																
Targeted extraction and bycatch of coastal fish																																
Targeted extraction and bycatch of cod																													NA	NA	NA	NA
Targeted extraction and bycatch of flatfish																													NA	NA	NA	NA
Targeted extraction and bycatch of pelagic fish																																
Targeted extraction and bycatch of salmon																																
Targeted extraction and bycatch of seatrout																																
Targeted extraction and bycatch of eel																																
Disturbance of harbour porpoise																															NA	NA
Disturbance of seals																																
Disturbance of seabirds																																
Disturbance of Species: obstructions (dams)																																
Intentional killing of seabirds																																
Intentional killing of seals																																
Input of PFOS																																
Input of TBT																																
Input of mercury																																
Input of diclofenac																																

Achievement of good state by the proposes new measures

The analysis on the probability to reach good state for the new measures evaluates the probability to reach good state or improvements in state with respect to different state components with existing and new measures. The results presented in this section for the proposed new measures only cover the impacts resulting from reductions in physical loss and disturbance of habitats and reductions in fish extraction and disturbance. Also, for concentrations of hazardous substances the reductions in the inputs of corresponding substances affect the results (e.g. the reduction in the input of mercury only affects heavy metal concentration). Further, there are a few measures that affect state components directly.

The linkages between inputs of pressures and pressures affecting state were not quantified for all pressures, and therefore the impacts related to some of the key pressures are not covered in the results. These include eutrophication, non-indigenous species, human induced food web imbalance, changes in hydrologic conditions and freshwater or land habitat loss/degradation. According to the expert data used in the analysis, the reductions in some pressures such as noise do not have an impact on the assessed state components, but they may affect other state components like mammals which could not be included in the analysis due to insufficient expert data. The overview of different pressures affecting assessed state components and quantification of linkages between the reduced pressure inputs and pressures affecting state are shown in Figure 3. For the significances of different pressures for individual state components see topic specific SOM reports for existing measures. Finally, as concluded in the previous subsection on projected pressure reductions, not all effects of measures on pressures could be quantified, and consequently their effects do not lead into reductions in total pressures or increases in probabilities to reach good state or improvements in state for the state components.

For the reasons above, the results presented in this section on probability to achieve good state or improvement in state and on reductions in total pressures are underestimations in a sense that they do not cover the impacts that all input pressure reductions could have on the state components. However, by and large, one could argue that reduction in input pressure does not imply reduction in the pressure affecting state, since reduction in pressure input only prevents further accumulation of the pressure.

The effects of excluded pressures on the results are shown in Tables 19 -23 as maximum possible pressure reductions. This means a level of pressure reduction that can be achieved (of the total 100%) with those pressures that are included in the analysis.

Improving the state of benthic habitats

According to the results, the proposed new measures would reduce total pressure with respect to the benthic habitats more than the existing measures (Table 19). This is clear for all the five benthic habitat types and all the assessment areas. Consequently, the probability to achieve a noticeable improvement in the state of benthic habitats would

increase significantly (Table 19). As thresholds for good state have not been set, the estimation was made as a 'noticeable improvement in state'.

According to Table 19, the included pressures covered by maximum only 28-58% of the total pressure affecting the benthic state components and therefore, the real state improvements may be higher. See the topic specific SOM reports for the specific pressures not included in the analysis. The new measures that affect the state results for benthic habitats are G21-G23, G25-G27, G38 and G57-G59, as well as G20 that directly improves the state of hard substrate epifauna dominated communities. An overview of new measures affecting different state components is provided in Table 14. Although no estimates are available to justify that claim, the new measures reducing excluded pressures such as eutrophication and changes in hydrological conditions will likely have additional positive impact on the state of benthic habitats.

Table 19. Total pressure reduction and achievement of a noticeable improvement in the state of benthic habitats with the existing measures ('E') and with both the existing and new measures ('E+N'). As eutrophication pressures were not included in the analysis, the table also shows what is the maximum possible total pressure reduction achievable.
Colour scale for the percent reduction in pressures: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

State component	Assessment area	Total pressure reduction (%) [10 percentile – 90 percentile]		Probability to achieve a noticeable state improvement (%) with expected pressure reduction [10 percentile – 90 percentile]		Maximum possible pressure reduction due to model coverage (%)
		E	E+N	E	E+N	
Hard substrate vegetation dominated community	Kattegat	6 [4-9]	14 [12-16]	0 [0-0]	7 [3-12]	36
	Southern Baltic	10 [7-14]	21 [19-23]	1 [0-5]	15 [10-22]	43
	Eastern Baltic	4 [3-6]	11 [10-12]	0 [0-0]	3 [2-5]	28
	Northern Baltic	5 [2-9]	16 [14-18]	0 [0-0]	<1 [0- <1]	32
Soft substrate vegetation dominated community	Kattegat	Insufficient data				
	Southern Baltic	11 [7-15]	24 [21-26]	3 [0-8]	28 [20-34]	47
	Eastern Baltic	7 [4-9]	19 [17-21]	1 [0-3]	24 [18-28]	33
	Northern Baltic	10 [3-17]	30 [26-33]	0 [0-8]	33 [21-33]	46
Hard substrate epifauna dominated community	Kattegat	9 [5-13]	20 [17-22]	2 [0-8]	25 [18-30]	46
	Southern Baltic	12 [8-17]	26 [23-29]	3 [0-8]	32 [23-42]	46
	Eastern Baltic	9 [6-13]	25 [22-27]	2 [0-9]	48 [39-55]	43
	Northern Baltic	6 [2-11]	19 [17-21]	0 [0-1]	28 [23-32]	39
	Kattegat	12 [7-18]	24 [20-28]	8 [1-21]	34 [27-42]	28

State component	Assessment area	Total pressure reduction (%) [10 percentile – 90 percentile]		Probability to achieve a noticeable state improvement (%) with expected pressure reduction [10 percentile – 90 percentile]		Maximum possible pressure reduction due to model coverage (%)
		E	E+N	E	E+N	
Soft substrate infauna dominated community	Southern Baltic	15 [10-20]	30 [27-34]	16 [1-28]	45 [40-52]	57
	Eastern Baltic	9 [6-13]	20 [17-22]	2 [0-7]	21 [14-24]	34
	Northern Baltic	7 [2-13]	23 [20-25]	0 [0-0]	<1 [0-2]	34
Coarse substrate infauna dominated community	Kattegat	Insufficient data				
	Southern Baltic	15 [10-21]	32 [29-36]	10 [2-21]	50 [42-60]	58
	Eastern Baltic	Insufficient data				
	Northern Baltic	Insufficient data				

Improving the state of waterbirds

The estimated results cannot be presented due to insufficient expert data. The set of proposed new measures included two types of measures that would very likely improve the state of waterbirds: marine protected areas and marine spatial planning measures (G57-G59), which decrease disturbance in various bird habitats, decrease bycatch mortality and improve feeding conditions (see measures in Table 12).

Improving the state of marine mammals

The results cannot be presented due to insufficient expert data. The measures improving marine protected areas – especially the strictly protected areas – and requiring the use of pingers will reduce bycatch mortality of mammals and especially harbor porpoises (see measures in Table 12).

Improving the state of commercial fish

The proposed new measures will likely improve the state of commercially exploited fish stocks (Table 20). Especially the state of herring stocks in the Baltic Proper and Gulf of Finland and in the Gulf of Bothnia as well as the Baltic sprat stock were estimated likely to be improved. The measures affecting the state results for commercial fish stocks are G21-G23, G25, G26-G27 (sprat only), G38, and G57-G59. The included pressures covered 43-56% of the total pressure reduction, again indicating that new measures targeting the excluded key pressures could have a positive impact on the state of commercial fish stocks.

Table 20. Total pressure reduction and achievement of good state of commercial fish stocks with the existing measures ('E') and with both the existing and new measures ('E+N'). As eutrophication and noise pressures were not included in the analysis, the table also shows what is the maximum possible total pressure reduction achievable.
Colour scale for the percent reduction in pressures: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

State component	Assess-ment area	Total pressure reduction (%) [10 percentile – 90 percentile]		Probability to achieve GES (%) with expected pressure reduction [10 percentile – 90 percentile]		Probability (%) to achieve specific state improvement with expected pressure reduction [10 percentile – 90 percentile]						Maximum possible pressure reduction due to model coverage (%)
						10% state improvement		25% state improvement		50% state improvement		
		E	E+N	E	E+N	E	E+N	E	E+N	E	E+N	
Herring												
SD 20-24, spring spawners		23 [16-29]	30 [25-34]	0 [0-0]	0 [0-1]							47
SD 25–29 and 32, excluding the Gulf of Riga		19 [13-24]	29 [25-33]	58 [43-68]	73 [69-76]							56
SD 28.1 (Gulf of Riga)		Insufficient data										
SD 30-31		20 [14-27]	28 [23-32			66 [25-84]	84 [78-86]	3 [0-18]	19 [16-21]	1 [0-5]	5 [2-7]	47
Cod												
Western Baltic		Insufficient data										
Eastern Baltic		Insufficient data										
Sprat												
SD 22–30 and 32		18 [13-23]	24 [20-27]	38 [24-45]	46 [40-53]							43
Plaice												
Baltic Sea, excluding the Quark and Bothnian Bay		Insufficient data										

Improving the state of migratory fish

The proposed new measures (G16 (seatrout only), G25-G27 and G57-G59) will further reduce pressures affecting migratory fish and increase the probability of improved state (Table 21). While the results do not show the impacts of reductions in riverine habitat loss or in changes of hydrological conditions, there were strong proposed measures to

reduce the riverine obstacles (G16). Given that the included pressures covered 24-56% of the total pressure reductions, new measures targeting the excluded key pressures likely have a positive impact on the state of migratory fish stocks.

Table 21. Total pressure reduction and achievement of good state of migratory fish with the existing measures ('E') and with both the existing and new measures ('E+N'). As eutrophication and several riverine pressures were not included in the analysis, the table also shows what is the maximum possible total pressure reduction achievable. Colour scale for the percent reduction in pressures: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

State component	**Assessment area**	**Total pressure reduction (%)** [10 percentile – 90 percentile]		**Probability to achieve GES/environmental targets (%) with expected pressure reduction** [10 percentile – 90 percentile]		**Probability (%) to achieve specific state improvement with expected pressure reduction** [10 percentile – 90 percentile]						**Maximum possible pressure reduction due to model coverage (%)**
						10% state improvement		**25% state improvement**		**50% state improvement**		
		E	**E+N**	**E**	**E+N**	**E**	**E+N**	**E**	**E+N**	**E**	**E+N**	
Salmon AU	AU 1-2	Insufficient data										
	AU 3	Insufficient data										
	AU 4	Insufficient data										
	AU 5	Insufficient data										
	AU 6	Insufficient data										
Eel	Baltic Sea	7 [4-10]	14 [12-16]	0 [0-0]	0 [0-0]							26
Sea trout	Gulf of Bothnia	7 [4-10]	20 [15-25]			0 [0-0]	3 [1-7]	0 [0-0]	3 [1-6]	0 [0-0]	2 [1-4]	45
	Gulf of Finland	15 [9-20]	29 [24-32]			16 [0-40]	75 [55-87]	0 [0-4]	49 [19-56]	0 [0-0]	0 [0-1]	56
	Western Baltic	7 [4-10]	20 [14-26]			1 [0-2]	9 [4-14]	0 [0-0]	2 [1-5]	0 [0-0]	0 [0-0]	41
	Eastern Baltic	9 [6-12]	21 [18-24]			0 [0-6]	38 [34-45]	0 [0-0]	6 [0-20]	0 [0-0]	0 [0-0]	46
	Southern Baltic	6 [4-8]	12 [10-13]			0 [0-0]	2 [0-4]	0 [0-0]	0 [0-0]	0 [0-0]	0 [0-0]	24

Improving the state of coastal fish

The proposed new measures (G09-G10, G21-G23, G25-G27, G38 and G57-G59) were estimated to at least double the pressure reductions compared to existing measures (Table 22; an exception is the cyprinids in the Swedish coastal area). The results also include the direct positive impacts of measure G20 on the state of perch and coastal piscivores. Consequently, the probabilities to reach good state or good improvements in state also increased. The included pressures covered 41-100% of the total pressure reduction, once again indicating that new measures targeting the excluded key pressures could have a positive impact on the state of coastal fish stocks.

Table 22. Total pressure reduction and achievement of good state of coastal fish with the existing measures ('E') and with both the existing and new measures ('E+N'). As eutrophication pressures and human induced foodweb imbalance (inter alia) were not included in the model, the table shows what is the maximum possible total pressure reduction achievable. Colour scale for the percent reduction in pressures: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

State component											
Assessment area	**Total pressure reduction (%)** [10 percentile – 90 percentile]		**Probability to achieve GES (%) with expected pressure reduction** [10 percentile – 90 percentile]		**Probability (%) to achieve specific state improvement with expected pressure reduction** [10 percentile – 90 percentile]						**Maximum possible pressure reduction due to model coverage (%)**
					10% state improvement		**25% state improvement**		**50% state improvement**		
	E	**E+N**	**E**	**E+N**	**E**	**E+N**	**E**	**E+N**	**E**	**E+N**	
Perch and other coastal piscivores											
Gulf of Bothnia	22 [10-33]	43 [37-48]	13 [10-47]	69 [57-79]							59
Gulf of Finland	14 [6-21]	37 [33-41]			5 [0-47]	99 [99-100]	Insufficient data				57
Gulf of Riga	Insufficient data										
Central (Swedish coastal areas only)	20 [9-30]	41 [36-46]	0 [0-0]	5 [5-8]							59
Eastern Gotland Basin (Latvian & Lithuanian coastal areas only)	Insufficient data										
South (Polish coastal areas only)	12 [8-17]	27 [24-29]			75 [18-92]	100 [100-100]		86 [80-92]		13 [12-15]	41
Cyprinids and other mesopredators											
Gulf of Bothnia	13 [6-21]	29 [25-32]	0 [0-0]	3 [0-8]							41
Gulf of Finland	Insufficient data										
Gulf of Riga	Insufficient data										
Central (Swedish coastal areas only)	19 [9-27]	32 [28-36]	0 [0-0]	0 [0-0]							48
South (Polish coastal areas only)	15 [9-20]	32 [29-35]			67 [31-75]	100 [99-100]	6 [0-49]	78 [72-84]	0 [0-0]	0 [0-0]	48
Eastern Gotland Basin (Latvian & Lithuanian coastal areas only)	Insufficient data										
Flounder											
Central (Swedish coastal areas only)	16 [5-26]	33 [28-37]	0 [0-0]	0 [0-0]							46
Eastern Gotland Basin (Latvian & Lithuanian coastal areas only)	Insufficient data										
Southwest (Danish coastal areas only)	18 [7-28]	67 [60-74]	100 [100-100]	100 [100-100]							100
South (Polish coastal areas only)	19 [12-26]	41 [38-45]			85 [73-88]	99 [98-100]	51 [43-83]	87 [86-93]	43 [43-43]	70 [60-81]	63

Improving the state for concentration of hazardous substances

The new measures that affect the state results for hazardous substances are G07, G21-G23, G25-G27, G38, G41 (only for diclofenac concentration), G42 and G57-G59 (Table 23). The measures result in increased expected total pressure reductions (8-20%) for all substance concentrations, but only increase the probability to reach good state for diclofenac concentration. The included pressures covered 61-85% of the total pressure reduction, indicating that new measures targeting the excluded key pressures could have a positive impact on the concentrations of hazardous substances, but the roles of key pressures are in average not as significant as for the state components of other topics.

Table 23. Total pressure reduction and achievement of good state of migratory fish with the existing measures ('E') and with both the existing and new measures ('E+N'). As eutrophication and several riverine pressures were not included in the analysis, the table also shows what is the maximum possible total pressure reduction achievable. Colour scale for the percent reduction in pressures: 0-10%, 10-20%, 20-40%, 40-60%, 60-100%.

State component	**Assessment area**	**Total pressure reduction (%)** [10 percentile – 90 percentile]		**Probability to achieve GES/environmental targets (%) with expected pressure reduction** [10 percentile – 90 percentile]		**Maximum possible pressure reduction due to model coverage (%)**
		E	**E+N**	**E**	**E+N**	
Mercury concentration	Baltic Sea	20 [10-27]	25 [17-32]	0 [0-0]	0 [0-0]	61
TBT concentration	Baltic Sea	-2 [-14-7]	7 [-4-15]	0 [0-0]	0 [0-0]	75
PFOS concentration	Baltic Sea	14 [6-23]	17 [9-25]	13 [0-13]	13 [4-13]	68
Diclofenac concentration	Baltic Sea	0 [-3-2]	8 [4-13]	0 [0-2]	12 [4-17]	85

5. Environmental and societal side effects of the proposed new measures

HELCOM thematic expert workshops [15] discussed each of the proposed new measures. As the focus of the workshops was in identification of environmental side effects and links to the climate change, these considerations were supplemented by economic and societal effects based on views of Finland's expert workshop for the preparation of the national programme of measures. However, all economic and societal comments from the above-mentioned HELCOM workshops were also included. Tables 24-31 present all the side effects, but they did not influence the analyses of sufficiency of measures or cost-effectiveness of measures. The initially proposed new measures were grouped to account for thematic overlaps among the measures. However, the original measure names are given as footnotes of the tables.

Table 24. Side effects of the proposed new measures addressing nutrient inputs. Footnotes refer to the original HELCOM proposals, some of which were combined due to overlaps. Symbols: + positive effect, - negative effect, * indirect effect.

Measure name	Side effects
Regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea (1	+ decreasing harmful impacts at sea
Reduce harmful impact of grey water discharges from Baltic Sea shipping (2	+ decreasing harmful impacts at sea; - the use of tank trucks instead of fixed PRF may have negative side effects
Measures to minimize the discharge of food waste from ships in the Baltic Sea	+ decreasing harmful impacts at sea; + effect on food webs; + effects for circular economy (circulated food as biofuels and energy)
Mussel farming to reduce nutrients at sea (3	+ reduce the impact of spreading non-indigenous species in the indigenous mussel population - taking up benthic space - introduction of plastics and microplastics and noise; - biodiversity impacts; - introduction of non-indigenous species
Reduce nutrient losses to zero from dry bulk fertilizer storage and handling in Baltic ports	+ reduce nutrient loads + benefits to biodiversity; + improved air quality in ports and nearby municipalities; + reduce waste of natural resources

[15] HELCOM BSAP UP workshop on maritime activities, including underwater noise, non-indigenous species and response actions, for the consideration of proposed new actions; HELCOM BSAP UP workshop on biodiversity, including extraction of species and spatial measures, for the consideration of proposed new actions; HELCOM BSAP UP workshop on eutrophication for the consideration of proposed new actions; HELCOM BSAP UP workshop on hazardous substances and litter for the consideration of proposed new actions .

Reduce discharges of cargo residues from shipping in the Baltic Sea [4]	+ reduce input of hazardous substances; + synergies if PFR can be used both for hold washwaters and sewage treatment
Prioritising the use of constructed wetlands to mitigate nutrient, microplastic and pharmaceutical residue leakage to the Baltic Sea and its water bodies	+ creating green spaces for biodiversity; + synergistic effects (all substances); +/- effect on birds, fish and other animals + improves water quality; - requires clean up of microplastic and hazardous substances; - risk for groundwater/drinking water being affected
Reducing internal phosphorus loads by metal bounding	+/- potential positive or negative effects depending on the technique used. + Status of fish stocks might get better due to enhanced state of the marine environment - Risks for negative side effects but difficult to quantify - toxic risks for species and fish (causing fish deaths) possible

1) Includes "Actions to further reduce nutrient input of shipping into the Baltic Sea" and "Proposal to regulate sewage discharges from cargo ships to reduce nutrient input into the Baltic Sea".
2) Includes "Actions to reduce harmful impact of grey water discharges from Baltic Sea shipping" and "Proposal to develop a roadmap for managing grey water discharges from ships to reduce nutrient input into the Baltic Sea".
3) Includes "Removal of nutrients from the coastal zone by the use of mussel mitigation cultures" and "Measures related to restoration of coastal habitats - 9. Reducing nutrient loading by farming and harvesting blue mussels".
4) Includes "Develop a HELCOM joint submission to IMO with the intention to recognize nutrients in cargo hold washing water as Harmful for the Marine Environment in the Baltic Sea.", "Limit the discharge of cargo residues from shipping in the Baltic Sea (e.g. vegetable oil and fertilizers)" and "Develop an adequate network of Port Reception Facilities (PRFs) in Baltic ports to receive ship hold washing water".

Table 25. Side effects of the proposed new measures addressing fisheries and fish.
Explanations in Table 24.

Measure name	**Side effects**
Seasonal closures in coastal waters	+ species and communities would benefit
Restore functional populations of Baltic sturgeon by implementing HELCOM Baltic Sea Sturgeon Action Plan	+ other migratory species and habitats
Restoration of coastal spawning habitats	+ habitat condition; + status of fish stocks; + food webs; + biodiversity; - potential effects on species other than fish; - may disturb natural succession of flads
Restocking of marine areas with fry of European Eel (*Anguilla anguilla*)	Not specified
Prioritising mitigation measures in rivers for eel and other fish migration [1	+ effects on other migratory species; + balancing food webs (top-down control); + biodiversity; + resilience on population level; + ecological status of inland waters; + synergies with river basin management plans
Phase out all recreational fishing on eel by 2022	+ several ecosystem benefits; - recreational fishing targeting to other fish species
National environmental permitting authorities to take into account possible impacts on weak migratory fish stocks, particularly salmon, as recognized by ICES or nationally, and how this may compromise the ability	+ healthy stream/river environment

to reach agreed river specific fish population targets	
Development of alternative fishing gear to replace gillnets	+ good alternative gears could lead to reduced use of pingers, leading to overall positive effects. +/- changes in the selectivity of the gear with respect to fish species could have either positive or negative side effects;
Concrete steps to make progress on cooperation between HELCOM and fisheries management (e.g. Baltfish) to improve implementation of BSAP	Not specified
Catch regulations in coastal waters	Not specified
Biomanipulation to remove cyprinds and sticklebacks and rehabilitate coastal ecosystem function	Not specified

1) Includes " Prioritising mitigation measures in rivers for eel and other fish migration" and " Removal of unnecessary dams and migration barriers, especially in small waterways".

Table 26. Side effects of the proposed new measures addressing seabed. Explanations in Table 24.

Measure name	**Side effects**
Restoration of lost stony reefs (1	+ habitat condition, fish stocks, food webs and biodiversity; + mitigation of coastal erosion; + carbon fixation through epilithic macrophytes; +/- changes in hydrological conditions and sedimentation patterns ; - loss of the current habitat type and organisms; - potential establishment of NIS
Speed limits for recreational boating in shallow coastal areas and larger boats near shore	+ decreasing erosion, resuspension and turbulence + reducing underwater noise + increasing condition of seabed habitats and status of the marine environment; *+ improved habitat condition leading to improved condition of exploitable species
Implement appropriate protective curtains for the dredging operations to prevent dispersal and spread of material	´*+ best practices decreases impacts of dredging to the marine environment; *+ enhancing state of the sea
Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas	+ decrease pressures on coastal habitats; + decrease nutrient release through decreased sediment resuspension; *+ vegetation for spawning (e.g. pike). *- affecting species that benefits from fairways and harbours (common bleak)
Adoption of a moratorium on seabed mining in the Baltic Sea, including a moratorium on developing additional permissive regulations and exploitation and exploration contracts.	Not specified
Improved regulation and reporting of small-scale dredging	+ improve biodiversity and vegetation; *+ landscape improvement
Updating the efforts to limit the impacts of dredging, sediment extraction and other bottom disturbing activities in the Baltic Sea	+ improve biodiversity and vegetation; *+ landscape improvement
Limit and preclude dredging/extraction near protected	+ improve biodiversity and vegetation; *+ landscape improvement

areas and increased buffer zones round sensitive areas	- displacement of human activities
Restoration of eelgrass, *Zostera marina*	+ carbon retention, sediment stabilization, habitat provision, fish nursery grounds, nutrient retention; + increased biodiversity; - failed use of seeds cause net loss of *Zostera marina*.
Rehabilitation of hypoxic areas by oxygen pumping [2	+/- depending on the technique used. + status of fish stocks; - increased leakage of nutrients leading to eutrophication; - might disturb seabed.
Rehabilitation of anoxic, nutrient rich or polluted sediments by removal or coverage	+ species, habitats, biodiversity; + climate change adaptation; - release of nutrients.
Restoration of soft bottom macrophytes (other than eelgrass)	+ nutrient retention; - biomanipulation.
Rehabilitation of hard bottoms by establishment of artificial reefs	+ positive influence on some species; - other habitats might be lost.
Restoration of brown macroalgae, mainly *Fucus vesiculosus*	+ biodiversity, fish spawning; + whip-splash effect to reduce sedimentation
Restoration of blue mussel reefs	+ improved water quality; + nutrient retention; + habitat provision and habitat complexity.
Restoration of soft bottoms free of vegetation	+ species, habitats, biodiversity; + climate change adaptation
Restoration of coastal wetlands	+ overall effect to the state of the sea and biodiversity; + decreases input of plastics, hazardous substances and nutrients; + increased amount of spawning areas; + strengthening coastal fish populations; +carbon sequestration; + climate change adaptation; - species and habitats habitats replaced; - altered hydrology.
Elimination of invasive plant Elodea	+ biomass and nutrient removal; + decreasing eutrophication; + decreasing hypoxia/anoxia; + enhancing habitat condition; - risk to harvest other species.
Areas around windfarms as potential refugia	+ increased food source for seabirds; - higher risk of collision for seabirds; - economic impacts on fisheries;
Harvesting of reed and excessive vegetation	+ living conditions and habitats; + increased biodiversity; + decreasing eutrophication, hypoxia and anoxia; + climate change adaptation; - risk for release of microplastics, hazardous substances, nutrients and methane; - decreased nutrient retention; - risk to harvest other species
Specific measures to address and protect all biogenic structures	+ spillover effects to biodiversity + positive effects on fish stocks; - effects for specific species; - effects for fishing industry.

4) Includes "Restoration of lost stony reefs" and "Restoration of stony reefs in areas where these have previously been lost".
Includes "Rehabilitation of hypoxic areas by oxygen pumping" and "Mixing within deeper water layers to encourage oxygenation at the benthic-pelagic interface".

Table 27. Side effects of the proposed new measures addressing hazardous substances. Explanations in Table 24.

Measure name	Side effects
Implement restrictions on over-the-counter pharmaceuticals that are persistent and have an impact on the environment by making prescription by physicians compulsory	+ more control of what and how much is bought and discharged to nature; + positive effect for ecosystem components (e.g. diclofenac on birds); - risk if one drug gets restricted, another one might increase
Safe manure recycling	Not specified
Decreasing the emissions of hazardous substances from small scale emitters in urban areas (municipal entities, businesses and private households) by chemical-smart purchasing strategies, substitution and awareness raising campaigns	+ might affect a wide range of substances; - substitution from one to another substance
Enhance mitigation measures to decrease GHG emissions from shipping- Alternative fuels and sources of energy	+ improvements in air quality; + reduction of acidification of the sea +biodiversity; + reduced risks involving accidental oil spills etc. - methane slip as a result of using LNG as an alternative fuel; - land use effects due to the production of various alternative fuels
Ban on import and sale of metallic lead in fishing equipment	+ take-up by birds and seals would be reduced (less in food-chain

Table 28. Side effects of the proposed new measures addressing litter. Explanations in Table 24.

Measure name	Side effects
Ban (phasing-out) on non-degradable shot wads and information campaigns targeted at hunters	+ lowering the consumption of plastics; + birds ingesting less plastic
Ban on handing out free carrier bags	+ less animal entablement and ingestion; + less resources needed for waste management
Ban on mass balloon (>50 balloons) releases	+ less animal entablement and ingestion;
Development of a HELCOM guideline on establishment and operation of artificial turfs	+ food web side-effects; + benefits for terrestrial and aquatic environment in general; + changing human behaviour and raising awareness
Ensure no-special-fee system for marine litter applies to all passive fished waste, as well as all other wastes captured or generated in the Baltic Sea.	+ food web effects from less ghost fishing
Reduction of single-use plastics consumption at major events	+ awareness raising; + less resources to waste management

Table 29. Side effects of the proposed new measures addressing underwater noise. Explanations in Table 20.

Measure name	Side effects
Reducing continuous underwater noise from shipping and recreational boating [1]	+ species, habitats and biodiversity; + status of commercial fish stocks (if measure addressing spawning areas); + food web effects; + enhanced energy efficiency of the vessels; + decreased disturbance to seabed and less coastal erosion (lowered speed); + less ship emissions; - increased noise in new areas; - fishing pressure expanded to new areas
Reducing the impact of impulsive underwater sound on marine biodiversity [2]	*+ species distribution and behaviour; + less hazardous substances if ammunitions are not detonated;

6) Includes "Develop a road map to investigate underwater noise, including possible follow-up actions", "Reducing the impact of continuous underwater sound on marine biodiversity [from shipping]" and "Reducing the impact of continuous underwater sound from recreational boating on marine biodiversity"
7) Includes "Identify and implement Best Available Technique (BAT) and Best Environmental Practice (BEP) to mitigate noise emitting activities" and "Reducing the impact of impulsive underwater sound on marine biodiversity".

Table 30. Side effects of the proposed new measures addressing non-indigenous species. Explanations in Table 24.

Measure name	Side effects
Adoption and implementation of a HELCOM Roadmap on Biofouling Management [1]	+ less hazardous substances; + less fuel consumption; + less CO2 emissions, especially important for ice classed ships; + less noise emissions; - spreading of harmful species if hull wash water is not appropriately collected and managed
Ship's ballast water and sediments management (BWM) by the HELCOM parties' domestic merchant fleets and naval forces as a supplementary measure to control introductions and secondary spread of Harmful Aquatic Organisms and Pathogens (HAOP) in the Baltic Sea.	Not specified

1) Includes "Adoption and implementation of a HELCOM Roadmap on Biofouling Management" and "Work for the harmonized implementation of the IMO Biofouling Guidelines and Guidance documents, and further work toward the International Biofouling Convention by contributing to the work carried out in the International Maritime Organization (IMO)".

Table 31. Side effects of the proposed new measures addressing harbor porpoise, marine protected areas and maritime spatial planning. Explanations in Table 24.

Measure name	Side effects
Mandatory use of pingers [1]	+ can potentially mask anthropogenic underwater noise; + balancing food web; - effects of pingers on other biota (attracting seals)
Strict marine protected areas (no use/no take/no entry) [2]	+ state of biodiversity in general; + spillover to other areas; + potential to decrease fishing pressure; + less noise, human disturbance + secures higher resilience and provisioning of ecosystem services; - displacement of activities to other areas; - uncertainty regarding changes in the system
Effectively managed marine protected areas [3]	+ state of biodiversity in general; + spillover to other areas; + secures higher resilience and provisioning of ecosystem services
Maritime Spatial Planning (MSP) applying an ecosystem-based approach to support BSAP-objectives and targets and contributing to sustainable sea-based activities [4]	+ wider ecosystem effects; - potential trade-offs between environmental objectives

1. Includes "Guidelines and regulation of the design and use of acoustic deterrent devices" and "Mandatory use of Acoustic Deterrent Devices or other effective mitigation measures to minimize bycatch of the Baltic Sea harbour porpoise (Phocoena phocoena)".
2. Incudes "Designate no-use marine protected areas, that also function as scientific reference areas", "Establishment of no-take areas", "Strengthening piscivorous fish to rehabilitate coastal ecosystem function", "No further expansion of fishing effort to areas not already impacted by existing fishing activities" and "Reduction of fishing pressure and development of Good Environmental Status delineation, supported by no go areas to determine benthic species recovery and potentially natural communities".
3. Includes "Establish an effectively and equitably managed, ecologically representative and well-connected system of highly protected marine protected areas (MPAs), covering a minimum of 30 % of the Baltic Sea area by 2030. All MPAs shall include fully closed zones (complying with IUCN 1a category1) or be fully closed in their entirety, depending on the conservation objectives and needs of the specific site", "Protect functionally important ecosystem elements and ecologically significant areas in order to create a regionally coherent network", "Strengthening the management of the Baltic Sea MPA network by introducing key management elements to increase effectiveness of protection", "Enhanced protection of coastal fish habitats" and "Protection of habitats".
4. Includes "Maritime Spatial Planning (MSP) applying an ecosystem-based approach to support BSAP-objectives and targets and contributing to sustainable sea-based activities", "MSP to signal areas of high nature value" and "MSP should steer sea-based activities away from areas where they can cause serious damage or disturbance".

6. Discussion

Overview of the proposed new measures

Of the 133 new measures proposed to the update of the Baltic Sea Action Plan, 83 measures were perceived to have measurable effects on other pressures than land-based nutrients and were thus included in the analysis. After grouping the overlapping measures 59 measures remained for closer scrutiny. Eutrophication from nutrient inputs has been repeatedly identified as the main pressure to the Baltic Sea and this set of measures had altogether 33 original proposed new measures that address eutrophication. Seabed or pressures affecting it were the targeted by 32 original proposed new measures. Management of fishing or improvement of fish stocks were objectives for 22 original new measures. For the rest, ten new original measures address spatial planning or MPAs, eight address hazardous substances, seven address inputs of litter, six address marine mammals or pressures on them, five address underwater noise, one addresses seabirds, and three measures target non-indigenous species.

Will the proposed new measures improve the state of the Baltic Sea?

The proposed new measures will make a clear difference to the existing BSAP by reducing several key pressures of the Baltic Sea marine environment and also directly improve states of species and habitats in the area. The analysis estimated that almost all the assessed inputs of pressures would decrease as a result of the new measures.

High uncertainties were associated with the estimations of improving the state of the Baltic Sea. The analysis couldn't confirm that good state of the Baltic Sea could be reached with the new measures. It was, however, shown that the probabilities to reach good state (or improve the state) increased for almost all state components. The state of marine mammals or waterbirds were not, however, assessed due to insufficient expert data.

The SOM analysis was not able to include effects of some of the key pressures such as eutrophication, NIS, freshwater or land habitat loss or changes in food webs and hydrologic conditions for total pressure reductions and state improvements. The included pressures for the new measures and assessed state components consisted only of physical disturbance and loss of habitats, and fish related pressures. This resulted in severe gaps in the sufficiency analysis. Particularly, the lack of eutrophication is a severe limitation as nutrient inputs and the consequent eutrophication have been shown to be the most significant pressure to the Baltic marine environment (see e.g. SOM main report). Therefore, all the results indicating change in state of species, habitats or concentrations are likely underestimations. However, excluding the impacts of eutrophication and other key pressures allows the closer inspection of included pressures which impacts would have otherwise been overshadowed with the impacts of these more prominent pressures.

Which proposed new measures are cost effective?

Measures to reduce pressures and impacts on marine environment can broadly be divided into two types: spatial measures addressing multiple pressures but in limited area (e.g. MPAs) and specific measures to a human activity which are applicable to the entire region. Selecting between these two types is not simple but sometimes necessary for good management decisions. The proposed new measures to the BSAP include both types and our analysis indicates that both can be effective. The spatial measures – strictly protected areas, marine protected areas and maritime spatial planning – all showed potential to significantly reduce multiple pressures, given that the management plans allow restrictions on the key human activities. Similarly, more specific measures were proposed, for example, to limit recreational fishing of eel, build fishways to rivers, reduce noise from shipping and manage ballast water discharges.

Spatial measures can also be more specific as is the case for some local measures like artificial (or restored) wetlands, stormwater ponds, mussel farms and almost all measures to reduce leakage of nutrients from agriculture, animal husbandry and forestry. Evidence for their local effectiveness is clear but the regional effectiveness depends on the number of sites constructed or managed. Especially the artificial wetlands have proven to be promising. They can be used as tertiary treatment in wastewater treatment, stormwater ponds, agricultural wetlands and artificial fish spawning habitats. In all these roles, wetlands retain hazardous substances, pharmaceuticals, microplastics, nutrients, organic matter and suspended solids. In coastal areas, the wetlands link terrestrial and marine food webs and can form biodiversity hot spots.

The challenge of the sufficiency analysis in this report was that the extent of the application cannot be accurately predicted for some measures. Therefore, the SOM analysis for proposed new measures relied on three scenarios where low, medium and high extents were estimated (see Methods). The results presented in this report were projected for the medium scenario, but results for the low and high scenarios for the projected pressure reductions and impacts of individual measures on pressures are also given in Appendix A. If the high/low scenario were assumed, the pressure projected pressures reductions and impacts of individual measures on pressures would be higher/lower, in particular for spatial measures such as MPAs.

Effectiveness is not only about reducing pressures but reducing pressures that are significant for state components. Even if a measure is effective only in reducing a single pressure, it can result in total pressure reductions and state improvements for multiple state components. For example, the measure G23 “Improved coastal planning to concentrate movement of smaller vessels in sensitive and shallow coastal areas” was estimated to reduce only physical disturbance of marine habitats. However, because this is a significant pressure for 12 of the assessed 15 state components, its total impact calculated over state components is significant. Taking into consideration both the impact over state components and the expected costs of measures, the measure G23

was estimated to be one of the most cost-effective measures of the analysis. Of course, the results based on costs and impact of measures should be considered merely demonstrative due to data gaps and uncertainties in data, but they reveal the different aspects (effect, significance and costs) that constitute cost-effectiveness.

The cost-impact ratio for measures was calculated using both relative %-impact defined as the impact in closing the gap between pressure reduction resulting from existing measures and pressure reduction required for good state or improvement in state, and as an absolute %-impact in reducing the pressure. The relative definition has been used before in cost-effectiveness analyses for MSFD programmes of measures (see for example Oinonen et al. 2016 and Kontogianni et al. 2015), but the SOM approach allows also the use of more absolute definition. The absolute impact does not take into account the amount of required pressure reduction, but the relative approach favors the measures reducing total pressures for state components with smaller gap between pressure reduction resulting from existing measures and pressure reduction required for good state. The selection of the proper approach to define the impacts would further depend on what is the value assigned to the impacts. Is the preferable outcome to reduce significant pressures or to reach the good state for as many state components as possible? For a cost benefit-analysis, the relative impacts could be applied when the benefit of reaching the good state is known, whereas the more absolute impacts could be more applicable when a value is assigned to a quantified change in the environment.

Are there gaps in the proposed set of new measures?

The proposed 83 original new measures cover a wide range of human activities, pressures and impacts; the majority (70/83) causing changes in human activities. A fraction (13/83) of the measures aim to improve the status of the environment directly, mainly through habitat or species restoration.

Many of the of the new measures were focused to **nutrient inputs and eutrophication**. The linkage between the reduction in nutrients and reduction in eutrophication affecting state components was not included in the SOM analysis, and there was lack of effectiveness data for the effectiveness of new measures targeted to nutrients. However, recent studies specifically addressing the topic have estimated that reaching the BSAP nutrient reduction targets is sufficient to allow recovery of the Baltic Sea ecosystem (Saraiva et al. 2019). The BSAP does not however clearly define how the targets can be reached and therefore the new measures are concrete additions to the updated BSAP.

Even 32 new measures were proposed to reduce physical pressures from the **benthic habitats** or directly improve their status. Many of the proposals are detailed down to concrete species-level actions, which explains the high number of proposals. No gaps were identified for this topic.

While many **fish species** were estimated to improve, eel, herring and sprat did not show such a trend. There are proposed measures specifically targeted for eel, but these were

not fully included in our analysis and therefore, the results may underestimate the impacts. The state of herring and sprat stocks depend on fishing quotas and, hence, their state may not require additional measures, but implementing the existing ones.

No specific measures were proposed to improve the status nor to reduce significant pressures affecting **seabirds**. Significant pressures to many seabird species are human disturbance (especially in their habitats), bycatch mortality and the predation by Raccoon dog and American mink. In the SOM analysis, data gaps prevented estimating any improvement in seabird status, but if the new measures to expand and strengthen the MPAs and effectively implement the MSP are implemented strongly, it is likely sufficient to allow positive development of many seabird populations. The set of proposed new measures did not, however, include any measures to eradicate the two non-indigenous predators, which is clearly a gap in the BSAP. Stronger MPA measures would also tackle the bycatch mortality and disturbance by human presence affecting **marine mammals**.

Five new measures were proposed to address the **underwater noise** pressure in the Baltic Sea, but especially the ones addressing dredging and construction activities lacked clarity with regard to what the concrete actions should be. It is recommended that the best environmental practices and best available techniques mentioned in these proposals would be spelled out in the BSAP in order to ensure their effective implementation.

Marine litter was addressed by seven proposed measures which target either micro litter inputs or more specific macro litter sources (e.g. carrier bags, shot wads from hunting, balloon releases). The existing measures from the EU legislation were estimated to be very effective in reducing the beach litter inputs (see WP6.1 SOM litter topic report). Litter was not included in the SOM analysis of new measures due to lack resources.

Only a few proposed new measures may reduce **hazardous substances**. According to our analysis, the inputs of hazardous substances do not seem to decrease significantly after adding these new measures to the analysis. The new measures cover cargo hold washing waters, small-scale emitters in urban areas, restrictions on selling of pharmaceuticals and retaining substances to tertiary wastewater treatments in constructed wetlands. Because of the limitations in the availability of effectiveness data, the effects of many of these measures are not included in the results. However, it is still obvious that the new measures do not reduce elevated concentrations of TBT and mercury, which are accumulated to the catchment area and to sediments of the Baltic Sea.

Non-indigenous species **NIS** were addressed by three new proposed measures. These measures are effective in further reducing the introductions of new species, but they do not affect previous introductions of species or their effect on state components.

What are the uncertainties and limitations of this analysis?

Predicting effects of measures in the Baltic Sea scale is an analysis with high uncertainties. In the ACTION project this was approached by primarily surveying expert knowledge and this was supported by literature surveys. The analysis heavily relied on the coherent modelling framework which allowed comparing all the different ecosystem components, pressures and measure effects. Nonetheless, there were wide statistical uncertainties in the results caused by multiple sources of uncertainty which are explained here. Additional uncertainties – related to the SOM model – are described in the WP6.1 SOM methodology report (HELCOM ACTION 2021b).

Knowledge gaps and uncertainties in measure effects. Most of the proposed new measures affect human activities at sea, on coasts or in the catchment area. One of the key factors of the SOM analysis was the effectiveness of these measures, and this was mainly estimated as a reduction of a pressure (or several pressures) from an activity. There is limited amount of literature available to define quantitative estimates for measure effectiveness, and for some measures the effectiveness values are based on expert opinions as in the SOM analysis for existing measures. This knowledge gap is one of the primary sources of uncertainty and gaps in coverage of this analysis.

Application extent. The application extent defines the (spatial) coverage of the measure within the relevant sub basins defined by the geographic extent. As described in Methods, the extent of implementation had to be predicted through scenario building. Three scenarios (low, medium, high) were defined for the measures that were assumed to require alternative application extent levels. These assumptions on measure application extents likely have a major impact on the results. The application extents were assumed equally distributed among the countries, sub-basins, and shares of the catchments where the measures are implemented, and changing this assumption would likely affect the results. This equal distribution also affects the cost results because the price level differs among countries. Further, differences in effectiveness in different sub-basins due to environmental differences were not considered in the application extent or effectivenes (e.g., measures related to mussel farms are likely more effective in the more saline southern Baltic Sea). The application extents, their descriptions and corresponding results are provided in Appendices A-C.

Knowledge gaps in the state of the environment and pressures affecting state components. The analysis requires information on the role of different pressures preventing the good state of state components. Although the Baltic Sea is one of the best-known marine ecosystems in the world, there are high uncertainties in pressure-state responses which can also vary depending on physical conditions like wave exposure, temperature or salinity. This uncertainty was visible in the wide data variability indicating which pressures should be reduced and by how much to reach good state or improvement in state. The relationships between reduced pressure inputs and pressures affecting state could not be quantified or implemented in the analysis for many of the key pressures. Thus, these effects are not covered in the results for state improvements. Although the state of the Baltic marine environment has been recently assessed in HELCOM HOLAS II process, many ecosystem components have unknown status or unknown thresholds for good status. This prevented a direct assessment of

measure effects and indirect methods were needed to estimate a 'noticeable improvement' or '10%/25%/50% improvement' (see topic specific SOM reports).

Uncertainty in implementation of the measures. There is no way to predict how strongly the Contracting Parties will implement the measures. Even the implementation of the existing measures carries high uncertainties. This is especially true for measures like marine protected areas where management of human activities can greatly vary depending on political will or legal frameworks used to implement the measure.

Uncertainty in cost estimation. The uncertainty in cost estimation depends on many factors. First the proposed new measures may not be concrete enough to explicitly define the scope and identify the cost components that should be included. For some cases for which the actual technical measures were not decided or defined in the proposed new measures, the cost may have been underestimated or not available. Second, there is the question whether the proper cost data can be found for all the identified cost components. Some of the proposed measures are so novel that no direct cost estimates were available. In such cases, some similar cost data was used for estimation which may lead to the third type of uncertainty: how compatible are the original cost data and the identified cost components of the new measures. In addition, there is also uncertainty in original cost estimates and in the cost type classification of the collected cost data. Further, for some measures, costs were estimated for the entire Baltic Sea using Danish price as reference, which may have led to overestimation. Finally, the application extents of the measures as well as other quantity assumptions used in the cost estimation likely lead to uncertainties. In addition to the uncertainties in cost estimation procedure itself, there is some disconnection between effectiveness and cost estimates, even though the cost estimation managed to follow the same geographic and application extents and quantities that were used for effectiveness assessment. Uncertainty also likely resulted from the use of different literature sources for effectiveness and cost data. In some cases, the unit used for effectiveness assessment did not match the unit used for cost which increases the uncertainty of the estimated costs applying unit transfer.

7. Conclusions

The results of the SOM analysis implied that new measures are needed in order to achieve good state of the marine environment in the Baltic Sea region. Our analysis showed that some of the proposed measures can be potentially more effective than others in reducing pressures and improving state and some of the measures can be overlapping when they target the same pressures and activities. It might not be optimal to implement overlapping measures and it could be feasible to focus on strong implementation of some of the measures that reduce important pressures for state components.

The annual total costs for all the proposed new measures, estimated based on partly defective cost data, ranges between 660 and 7 200 M€, with an expected value of 2650 M€. The costs of the measures vary significantly among measures, and costs could not be estimated for all measures based on available data. The cost impact ratio to assess cost-effectiveness was only defined for some measures and only with respect to some states and pressures. However, the cost impact ratios show that some measures may be more cost effective than others in reducing significant pressures for state variables, and that the cost impact ratio of individual measures can be driven both by the impacts on the state and the costs of the measure. It was also shown that the definition of impact (relative or absolute) affects the relative cost-effectiveness of measures, and careful consideration is required when choosing the appropriate approach and interpreting the results accordingly.

The HELCOM call for the new measures requested concrete actions and evidence for their effectiveness as well as possibilities for their implementation. Both the aspects were also evaluated by the HELCOM working groups and the remaining set of measures indicates a success in this respect. The sufficiency analysis indicated that the new measures reduce pressures and improve the state of marine environment even if some of the key pressures were excluded from the analysis. This underestimation likely means that the prosed new measures could result in higher pressure reductions and state improvements than what is shown by the results. The results can guide the future marine management and cater to specific management needs by indicating which of the measures are likely more effective than others in reducing specific pressures or reducing multiple pressures as well as by revealing the activity-pressures overlaps to avoid ineffective combinations of measures.

The analysis showed that spatial protection measures – be they for strict, general or sectoral protection – were the ones addressing most of the pressures and were also considered effective. The limitation of the spatial measures is their limited spatial extent. In addition, the history has shown that MPA management has been inadequate (e.g. European Court of Auditors 2020); this cannot be afforded in the future Baltic Sea management. However, the costs to properly enforce these measures can be high and the opportunity costs of protected areas may be significant (due to lost income in affected sectors) which can result in low cost effectiveness ranking compared to the other measures. Nonetheless, effective measures are not always costly. The estimated cost and the cost impact ratios show that administrative regulation measures such as spatial planning measures, fishery or boating regulations or requirements for best

available technology may have low costs but at the same time can they also be effective. According to our analysis, also the measures mitigating the migration barriers for fish in rivers are very effective (though focusing to a few species only). Such measures are already mentioned in the BSAP 2007, but the state of migratory fish stocks are still poor in many sub-basins of the Baltic Sea.

This analysis was a pilot attempt to assess the costs and effects of marine management measures on a regional Baltic Sea scale covering a variety of pressures and state components, and by applying a measure-activity-pressure-state framework. Several data gaps and sources for uncertainties were identified during this process and preceding SOM analysis for existing measures, and these gaps and uncertainties affected the results. As a conclusion more data and work are needed to quantify all the effects through the whole chain from measures to pressures to state in order to produce more reliable and comprehensive results. However, this analysis provides tools, methods and concepts that could be further developed and applied in future cost effectiveness and benefit analyses, and builds capacity on cost and effectiveness data needed for similar analyses.

8. List of Appendices

All appendices are given as separate Excel files available on the SOM workspace.

Appendix A: model input data of the new measures and results for all scenarios;

Appendix B: effectiveness of the new measures from the synopses and literature review;

Appendix C: cost database of the new measures.

Appendix D: pressure reduction by state component

9. References

Boteler, B., J. Tröltzsch, K. Abhold, M. Lago, T. T. Nguyen, E. Roth, E. Fridell, H. Winnes, E. Ytreberg, M. Quante, V. Matthias, J.-P. Jalkanen, L. Johansson, J. Piotrow, U. Kowalczyk, K. Vahter & U. Raudsepp (2015). SHEBA - Drivers for the shipping sector. SHEBA Project Report. https://www.sheba-project.eu/imperia/md/content/sheba/deliverables/sheba-d1.1_final.pdf

Brander, Luke. (2013). Guidance manual on value transfer methods for ecosystem services. UNEP

European Court of Auditors (2020) Marine environment: EU protection is wide but not deep. Special Report 26/2020. https://www.eca.europa.eu/en/Pages/DocItem.aspx?did=57066.

EUROSTAT (2020a). Purchasing power parities (PPPs), price level indices and real expenditures for ESA 2010 aggregates. https://ec.europa.eu/eurostat/databrowser/view/PRC_PPP_IND__custom_190564/default/table?lang=en (Accessed on 11 November 2020).

EUROSTAT (2020b). Euro/ECU exchange rates - annual data. https://ec.europa.eu/eurostat/databrowser/view/ert_bil_eur_a/default/table?lang=en (Accessed on 11 November 2020)

Evans, J.D., & Sezer, H. (2005). Social discount rates for member countries of the European Union. Journal of Economic Studies, 32(1), 47-59.

Hutton, G., & Baltussen, R. (2005). Cost valuation in resource-poor settings. Health policy and planning, 20(4), 252–259. https://doi.org/10.1093/heapol/czi025.

Kazlauskiene, Vilma. (2015). Application of Social Discount Rate for Assessment of Public Investment Projects. Procedia - Social and Behavioral Sciences. 213. 461-467. 10.1016/j.sbspro.2015.11.434.

OECD (2007), "Use of Discount Rates in the Estimation of the Costs of Inaction with Respect to Selected Environmental Concerns", OECD Papers, vol. 7/9, https://doi.org/10.1787/oecd_papers-v7-art28-en.

OECD (2018), Cost-Benefit Analysis and the Environment: Further Developments and Policy Use, OECD Publishing, Paris, https://doi.org/10.1787/9789264085169-en.

OECD (2020a). Inflation (CPI) (indicator). doi: 10.1787/eee82e6e-en (Accessed on 11 November 2020)

OECD (2020b). Purchasing power parities (PPP) (indicator). doi: 10.1787/1290ee5a-en (Accessed on 11 November 2020)

Oinonen, S., Hyytiäinen, K., Ahlvik, L., Laamanen, M., Lehtoranta, V., Salojärvi, J., & Virtanen, J. (2016). Cost-effective marine protection-a pragmatic approach. PloS one, 11(1), e0147085.

Kontogianni, A., Tourkolias, C., Damigos, D., Skourtos, M., & Zanou, B. (2015). Modeling expert judgment to assess cost-effectiveness of EU Marine Strategy Framework Directive programs of measures. Marine Policy, 62, 203-212.

Räike, A., Oblomkova, N., Svendsen, L. M., Kaspersson, R., Haapaniemi, J., Eklund, K., Brynska, W., Hytteborn, J.,
Tornbjerg, H., Kotilainen, P., Ennet, P., Kokorite, I., Sonesten, L., Plunge, S., Koch, D., Andresmaa, E., Frank-
Kamenetsky, D., Pecio, A., Sokolov, A., & Ejhe, H. (2019). Background information on the Baltic Sea catchment area for the Sixth Baltic Sea pollution load compilation (PLC-6). Helsinki Commission - HELCOM. https://helcom.fi/media/publications/PLC-6-background-report.pdf

Saraiva, S., Markus Meier, H.E., Andersson, H. *et al.* (2019) Baltic Sea ecosystem response to various nutrient load scenarios in present and future climates. *Clim Dyn* **52,** 3369–3387. https://doi.org/10.1007/s00382-018-4330-0.
Pihlainen, S., Zandersen, M., Hyytiäinen, K., Andersen, H. E., Bartosova, A., Gustafsson, B., ... & Thodsen, H. (2020). Impacts of changing society and climate on nutrient loading to the Baltic Sea. Science of the Total Environment, 731, 138935.

Hyytiäinen, K., Ahlvik, L., Ahtiainen, H., Artell, J., Huhtala, A., & Dahlbo, K. (2015). Policy goals for improved water quality in the Baltic Sea: when do the benefits outweigh the costs?. Environmental and Resource Economics, 61(2), 217-241.

Nainggolan, D., Hasler, B., Andersen, H. E., Gyldenkærne, S., & Termansen, M. (2018). Water quality management and climate change mitigation: Cost-effectiveness of joint implementation in the Baltic Sea region. Ecological Economics, 144, 12-26.

Hasler, B., Hansen, L. B., Andersen, H. E., & Termansen, M. (2019). Cost-effective abatement of non-point source nitrogen emissions–The effects of uncertainty in retention. Journal of environmental management, 246, 909-919.

Saikkonen, L. (2018). Cost-effective combination of measures to reduce the loads of plastic marine litter in urban areas: Case Turku region. BLASTIC project report. https://www.blastic.eu/wp-content/uploads/2018/10/combination-of-measures-to-reduce-the-loads-of-plastic-marine-litter.pdf

SOM report series
HELCOM. 2021a. HELCOM ACTION WP 6.1 Sufficiency of existing measures to achieve good status in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MainSOMReport
HELCOM 2021b. HELCOM ACTION WP 6.1 Methodology for the sufficiency of measures analysis. Available at: http://www.helcom.fi/SOM/MethodologyReport
HELCOM 2021c HELCOM ACTION WP 6.1 A practical guide to interpreting the SOM results. Available at: http://www.helcom.fi/SOM/PracticalGuide
HELCOM. 2021d. HELCOM ACTION WP 6.1 Sufficiency of existing measures for benthic habitats in the Baltic Sea. Available at: http://www.helcom.fi/SOM/BenthicHabitatsReport
HELCOM. 2021e. HELCOM ACTION WP 6.1 Sufficiency of existing measures for coastal fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CoastalFishReport
HELCOM. 2021f. HELCOM ACTION WP 6.1 Sufficiency of existing measures for commercial fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CommercialFishReport
HELCOM. 2021g. HELCOM ACTION WP 6.1 Sufficiency of existing measures for hazardous substances in the Baltic Sea. Available at: http://www.helcom.fi/SOM/HazardousSubstancesReport
HELCOM. 2021h. HELCOM ACTION WP 6.1 Sufficiency of existing measures for input of nutrients in the Baltic Sea. Available at: http://www.helcom.fi/SOM/NutrientsReport
HELCOM. 2021i. HELCOM ACTION WP 6.1 Sufficiency of existing measures for marine litter in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MarineLitterReport
HELCOM. 2021j. HELCOM ACTION WP 6.1 Sufficiency of existing measures for marine mammals in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MarineMammalsReport
HELCOM. 2021k. HELCOM ACTION WP 6.1 Sufficiency of existing measures for migratory fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MigratoryFishReport
HELCOM. 2021l. HELCOM ACTION WP 6.1 Sufficiency of existing measures for non-indigenous species in the Baltic Sea. Available at: http://www.helcom.fi/SOM/NISReport
HELCOM. 2021m. HELCOM ACTION WP 6.1 Sufficiency of existing measures for underwater noise in the Baltic Sea. Available at: http://www.helcom.fi/SOM/UnderwaterNoiseReport
HELCOM. 2021n. HELCOM ACTION WP 6.1 Sufficiency of existing measures for waterbirds in the Baltic Sea. Available at: http://www.helcom.fi/SOM/WaterbirdsReport
HELCOM 2021o. HELCOM ACTION WP 6.2 Sufficiency and cost-effectiveness of potential new measures to achieve good status in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CostEffectivenessReport