Methodology for the sufficiency of measures analysis

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Monitoring and assessment

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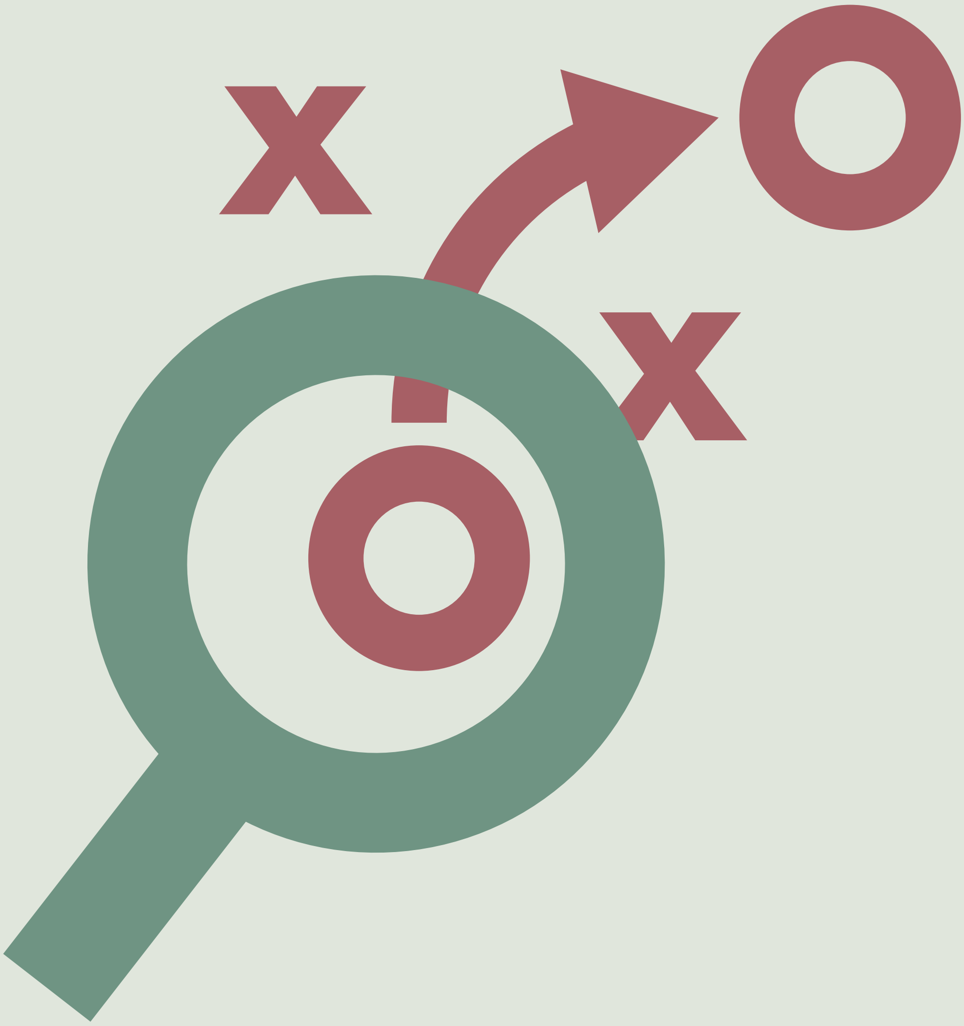

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This publication is a deliverable of the HELCOM ACTION project's work package WP6 - Sufficiency of measures: developing an approach to assess the sufficiency of existing measures to achieve GES, implementing the approach for selected topics, identifying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

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Foreword

This report has been written by the HELCOM ACTION project and HELCOM Secretariat. Several HELCOM groups have contributed to the development of the methodology of the SOM analysis. The ad hoc HELCOM Platform on Sufficiency of Measures (SOM Platform), HELCOM Gear Working Group and the HELCOM Expert Network on Economic and Social Analyses (EN ESA) have given general guidance on the development of the approach and data collection. Guidance and input to topic-specific methodology and data collection have been provided by SOM topic teams for hazardous substances, noise, litter and fish, SOM topic workshops for mammals, birds, hazardous substances, fish, and benthic habitats organized in the autumn 2019, and the Agri Group for the input of nutrients from agriculture. In addition, topic-specific contributions have been received from individual topic experts for mammals and birds.

Contributions of HELCOM groups were also vital in the data collection. The experts responding to the surveys represented HELCOM Expert Networks and Groups or were specifically nominated for the task by Contracting Parties via HELCOM Working Group and SOM Platform contacts. Dozens of experts around the Baltic Sea participated in the surveys, giving their expert opinions on challenging questions.

We wish to express our gratitude to all of those who contributed to the development of the methodology and data collection for the SOM analysis.

Methodology for the sufficiency of measures analysis

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PART I - OVERALL APPROACH TO ESTIMATE THE SUFFICIENCY OF MEASURES

1. Introduction

The aim of the sufficiency of measures (SOM) analysis is to assess improvements in environmental state and reductions in pressures that can be achieved with existing measures by 2030, and whether these are sufficient to achieve good environmental status (GES) in the Baltic Sea. It is based on estimating the status of the marine environment at a future point in time, given measures applied via existing policies, their implementation status, natural time lags, and the predicted development of human activities over the selected time period (2016–2030). This state of the marine environment is called the 'business-as-usual (BAU) state' (Figure 1). If the analysis indicates that GES is not achieved, then existing measures are not sufficient and additional measures are needed (or existing measures need to be strengthened).

The approach for the SOM analysis builds on concepts developed in the HELCOM SPICE project (Deliverables 3-3 and 3-4), applies state-of-the-art methods from scientific literature (e.g. Kontogianni et al. 2015 and Oinonen et al. 2016) and is in line with the approach taken by a number of the HELCOM Contracting Parties to analyse the effectiveness of measures for the first round of the EU MSFD Programme of Measures. Although the approach builds on previous concepts and analyses, it also takes significant steps forward by attempting to assess the effects of measures through activity-pressure-state linkage chains, and addresses these issues at the relevant spatial scale. The approach also considers predicted future changes in activities and the resulting changes in pressures on the Baltic Sea, whereas most of the previous analyses have assumed that these activities remain unchanged.

The main purpose of the SOM analysis is to support the update of the HELCOM Baltic Sea Action Plan (BSAP) by identifying potential gaps in achieving environmental objectives in the Baltic Sea with existing measures. In addition, the analysis can indicate, both thematically and spatially, where new measures are likely needed. Further, the linkage-chain approach makes it possible to assess what types of measures are potentially effective in improving the state of marine environment, given the spatial characteristics of state, pressures and human activities. Additional outputs of the analysis include information on, for example, the relative contribution of activities to pressures, effectiveness of measures types in reducing pressures from activities, most significant pressures affecting state components, pressure reductions required to achieve GES/status improvements, status improvements/pressure reductions from existing measures, and time lags between measures and environmental state. The purpose of the SOM analysis is not to retrospectively assess the implementation of BSAP and other related policies, but rather present the first attempt to quantify the effects of existing measures and policies on the environment.

Therefore, the SOM analysis can be seen as a tool contributing to the assessment of the gap to good status and thus the need for new measures or strengthening existing ones. In some cases, it can provide supporting information on where and what types of measures could be effective in reducing pressures. The results of the analyses are mainly based on expert elicitation, and thus they should be interpreted with the appropriate level of discretion. This approach was applied to cover an extensive array of topics across the region in a comparable manner, while each had markedly different characteristics and data flows. However, the structure of the assessment offers the potential for development towards the use of model and literature-based estimates, when such are available. As such, the results of the SOM analysis do not provide comprehensive or absolute statements on the reductions in pressures or improvements in state, and should be reviewed in relation to the results of other assessments when guiding management decisions.

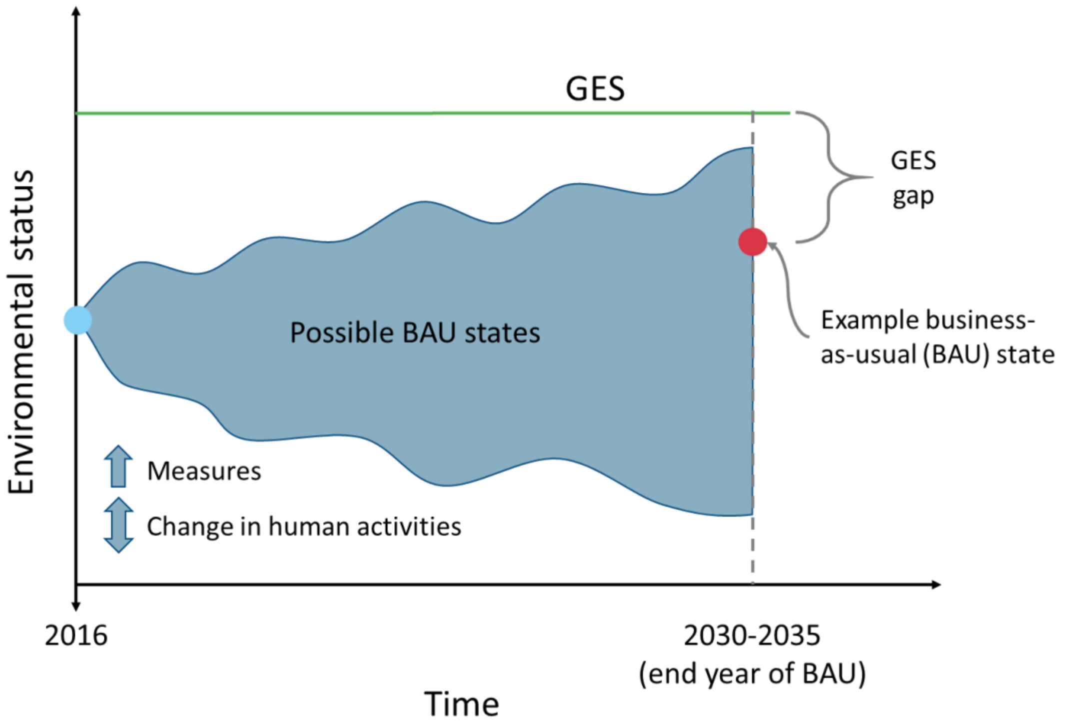

Figure 1. Illustration of the SOM analysis, the business-as-usual (BAU) state and gap analysis.

2. Overall approach

SOM analysis includes the following components (Figure 2):

Step 1. Existing measures and measure types, including measure-activity links
Step 2. Time-lags for measure effects on pressures
Step 3. Contribution of activities to pressures
Step 4. The effects of measure types on pressures and state
Step 5. Projected development of human activities
Step 6. Effect of changes in pressures on the state of marine environment
Step 7. Comparison of business-as-usual and good status and gap assessment
Step 8. Effect of time lags in the recovery of state components

The steps are described in detail in Section 3. The tool used for the SOM analysis is referred to as the SOM model (for details, see Part III).

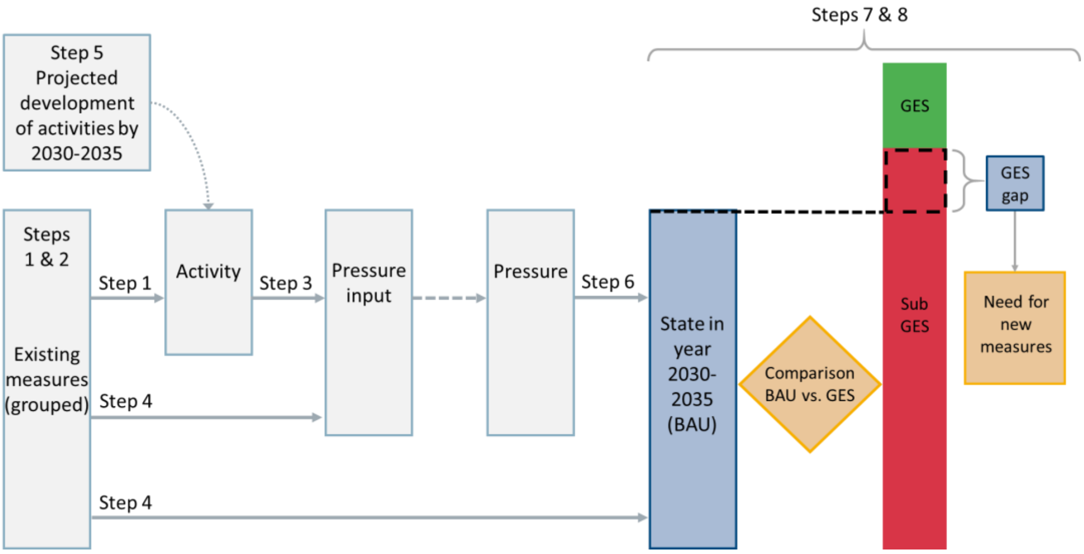

Figure 2. Schematic showing the main components and steps of the SOM approach. Linking existing measures with activities, pressures or state components; predicted changes in activities and pressures; comparison of the BAU state with GES; and estimation of the need for new measures. Note that the analysis for individual topics does not necessarily include all the above components and steps.

Existing policies and measures

Measures that are included in the SOM analysis need to be clearly defined. For all existing relevant policies (e.g. current BSAP, MSFD, WFD, EU Biodiversity Strategy 2020), the effect of the following existing measures[1] is included in the analysis:

1) implemented measures with unrealized effects on 2016 pressure levels
2) ongoing or partially implemented measures, and
3) planned measures that have not yet been implemented.

These are existing measures that can still affect pressures and environmental state within the time frame of the analysis (2016–2030). Measures which have already been implemented and fully affected pressures and environmental state by 2016 have been excluded, as no further improvement of status is expected during in 2016-2030. It is further assumed that all measures included in the SOM analysis will be fully implemented and their effect on reducing pressures is fully realized in the time frame of the analysis, independent of their current implementation status.

Actions in the HELCOM setting refer to 1) measures which are directly aimed at reducing pressures and improving the state of the environment, 2) management coordination aimed at establishing joint HELCOM principles for management, 3) monitoring and assessment, 4) data and information and 5) knowledge (HELCOM 2018e). All types of actions and measures have been included in the SOM analysis, except for monitoring and assessment, data and information and knowledge actions (e.g. coordination, developing indicators, setting targets, developing information systems/tools, research), which have no direct effect on environmental status.

Environmental topics covered

The SOM analysis is carried out for the same environmental themes (topics) as in the State of the Baltic Sea report (HELCOM 2018a). Altogether nine distinct topics are addressed in the analysis. The level and specificities of evaluation differ across topics. For biodiversity topics, the evaluation is conducted by habitat types (benthic habitats: 5 habitat types), species groups (fish: 2 species groups), species (fish: 5 species; birds: 6 species) and populations (fish: 7 populations; mammals: 8 populations). The evaluation units for biodiversity topics are further divided into geographic areas as appropriate. For litter, the analysis is limited to beach litter focusing on the 15 top litter items evaluated across 6 different areas. For hazardous substances, the evaluation is done at the Baltic Sea scale for four distinct substances: mercury, perfluorooctane sulphonate (PFOS), tributyltin (TBT) and diclofenac. For underwater noise, three distinct noise bands are evaluated across five different areas: continuous noise 63-125 Hz, continuous noise 2 kHz and impulsive noise with peak energy below 10 kHz. Eutrophication is primarily assessed as the input of nitrogen and phosphorus across 7 different areas, and non-indigenous species as the number of anthropogenic introductions of non-indigenous species at the Baltic Sea scale.

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[1] Note that the term *existing measures* covers measures in existing policies that have been implemented, are partially implemented or are planned to be implemented.

The GES threshold values agreed in HELCOM are used as the basis for the analysis where they exist (Figure 3). Test values for GES have been used where available. For mammals, birds, fish, benthic habitats, and hazardous substances, the SOM analysis assesses the state improvement achieved from existing measures and compares it with the pressure reductions required to achieve GES or specific improvements in state. For eutrophication (nutrient input) and non-indigenous species, the analysis entails comparing the pressure reductions from existing measures to the pressure targets that define the GES threshold values. For litter and noise, there are currently no agreed GES threshold values or quantitative pressure reduction targets in HELCOM, and thus proper gap analysis is not possible. For these topics, it is still possible to assess how much the existing measures will contribute to reducing pressures and improving the condition of the Baltic Sea. Decisions on these aspects have been made in collaboration with relevant SOM topic teams and other topic experts, who provided expert knowledge and support for most of the topics in the analysis in addition to the HELCOM ACTION project and HELCOM SOM Platform[2].

The effect of the existence of an agreed GES threshold on the analysis is further discussed in Steps 6 and 7.

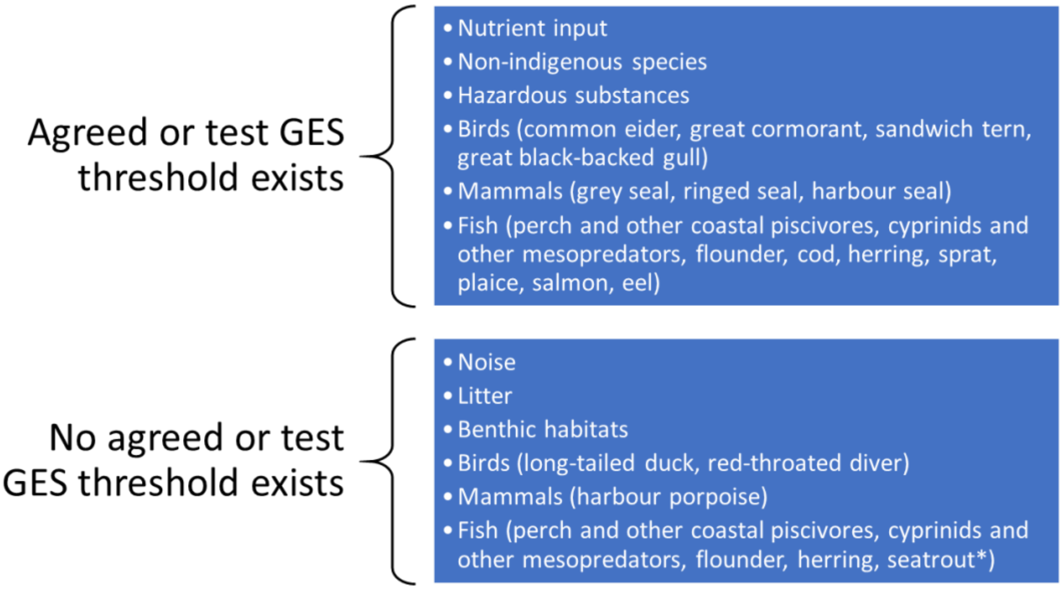

Figure 3. Environmental themes in the SOM analysis (topics). Listed topics and components may have further divisions by component, population, or area. For topics with a mix of components with and without established GES thresholds, the relevant components are in parenthesis. Fish components may appear in both categories due to varying presence of GES thresholds by area. *A GES threshold is present for seatrout but due to complications in adapting the baseline seatrout data to the SOM structure, the analysis does not utilize the GES threshold.

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[2] Expert inputs have been received from several HELCOM Groups, Networks and individual experts throughout the analysis. SOM topic teams were established for fish, hazardous substances, litter, noise, and non-indigenous species, and provided topic expertise for the analysis. In addition, expert support for benthic habitats and input of nutrients was available in the ACTION project. Moreover, representatives of relevant HELCOM Groups and Networks participated in designing the expert data collection.

Pressure inputs and pressures

The SOM analysis distinguishes between pressure inputs and pressures. It is often the case that the input of a pressure has been measured rather than the pressure itself. This occurs for a variety of reasons, including ease of measurement (e.g. primary introductions of non-indigenous species only requires monitoring programs to identify novel species while a systematic assessment of the effect of non-indigenous species would be a massive effort and need constant reassessment), generation of data relevant to regulation (e.g. tracking of industrial emissions), and/or the presence of significant time lags (e.g. changes in nutrient inputs will not have immediate effect on the effects of eutrophication). In the SOM analysis, there are three alternative ways how the pressure inputs and pressures are linked:

1. The pressure input and pressure are equivalent or assumed to be equivalent. This typically happens with pressures that have very short or no time lag, e.g. noise, bycatch, extraction of fish. This can also occur in other circumstances, depending on the topic structure and assumptions, e.g. the input of mercury is assumed to be equivalent to heavy metal pollution only when assessing the concentration of mercury, and not for any other state components in the SOM analysis.
2. Both the pressure input and corresponding pressure are present in the analysis, but no connection is made between them. This happens with pressures that are difficult to measure often due to subtle but ubiquitous impacts, e.g. non-indigenous species, most applications of hazardous substances, eutrophication.
3. Only the pressure is present in the analysis. This occurs for more complex pressures with no clear single input, e.g. human induced food-web imbalance, or for pressures outside the scope of the SOM analysis, e.g. river, lake or land habitat loss/degradation.

Time frame

The time frame of the SOM analysis is set to stretch from 2016 until 2030. The base year of the SOM analysis is set to 2016, which is the end year of the HOLAS II assessment period and the most recent state of the Baltic Sea assessment. The end year of 2030 allows for substantial impact from existing policies and measures, but does not stretch too far into the future to result in significant uncertainties due to changes in the climate, policies or scientific and technological advancements. The time frame is also consistent with the relevant target years of the updated HELCOM BSAP, the EU MSFD and the UN Sustainable Development Goals (SDGs).

The time frame of the SOM analysis does not determine the target year for implementing the measures in the updated BSAP. An end year is required to facilitate the SOM analysis in practice, and, for example, to determine the time frame for the scenarios on the future development of human activities (Step 5). Early implementation of measures likely increases the chances of measures having their full impact, and that impact being observed, within the given assessment period.

Geographical scale of the analysis

The geographical scale of the SOM analysis is aimed at supporting decisions from a regional Baltic Sea perspective. Differences in key factors such as distribution, natural processes or data availability influence the input at each step of the process. However, the overall SOM analysis is being carried out at the HELCOM scale 2 level (17 sub-basins) where found relevant.

The spatial resolution (level of detail) differs across the topics, steps and data components of the SOM analysis. In general, the geographic scale reflects the fewest number of distinct areas required to accurately describe the activities, measures and pressures relevant to each environmental topic. All areas are based on the 17 HELCOM sub-basins and range in size from a single Baltic Sea assessment to individual assessments for each sub-basin. The activity-pressure contributions (Step 3) are assessed at a variety of spatial resolutions based on data availability and expert knowledge. The effectiveness of measure types in reducing pressures (Step 4) and the effect of development of human activities (Step 5) are assessed for the entire Baltic Sea. The spatial resolution for the pressure-state linkages (Step 6) varies across topics similarly to the activity-pressure contributions, from the entire Baltic Sea to single sub-basins. The definition of the state component may already include a geographic element, for example, the population of the species in a specific part of the Baltic Sea. The geographical scales have been decided for each of the pressures and state components based on input from the SOM Topic Teams and various HELCOM Expert Groups and Networks.

Data requirements

Input data to the SOM analysis include expert judgment, existing literature, model outputs and other data sources adjusted to fit the purpose of the analysis (e.g. data products developed by HELCOM ACTION WP4 and HELCOM SPICE, and stock reports from ICES). Data availability varies substantially across topics and data components. The SOM model can function entirely based on expert opinion, and this is applied where required to cover the broad range of topics and the full spatial extent. The number of expert responses per topic, step and state component are reported with the results to indicate the amount of data for each element. Criteria have been developed to determine the format of presenting the results: quantitative, semi-quantitative/qualitative or not presented at all, based on the number of expert responses. The minimum acceptable number of responses depends on the result elements and view of topic experts. In addition, the presentation and discussion of the results is tailored to the quality and quantity of the available data.

3. Steps of the SOM analysis

Step 1. Existing measures

This section gives detailed information on SOM components related to existing measures and their level of implementation. Only measures having a clear effect on the environment are included in the SOM analysis. This excludes e.g. research, monitoring, coordination, developing indicators, setting targets, developing information systems/tools.

1a. Measures under existing policies (i.e. existing measures) have been identified to assess their effect on the marine environment. This includes global conventions, EU directives and regulations, regional HELCOM actions and national measures.

1b. The implementation status of the measure has been assessed, i.e. whether the measure 1) has been fully implemented and has unrealized effects on base year (2016) pressure levels, 2) has been partially implemented or implementation is ongoing, or 3) is planned to be implemented. The implementation status of measures included in the current BSAP has already been assessed in previous HELCOM processes, but for other measures (e.g. national MSFD measures), information on implementation status has been collected from Contracting Parties.

1c. These existing measures have then been categorized into ‘measure types’ which are the units used in the SOM surveys for the effectiveness of measures. An example of a measure type is ‘technical modification of fishing gears to reduce bycatch of harbour porpoise’. The categorization allows for simplifying the analysis (i.e. by aggregating similar type of measures) and linking them with activities and/or pressures (or in case of restoration measures, to state).

A majority of measures are linked with human activities, but some are directly linked to pressures (e.g. long-range transboundary pollution) and a few to state components (e.g. restoration, restocking) (Figure 2).

- If a measure is linked to an activity, i.e. the activity is restricted or changed, then one can follow the linkage framework and estimate the consequent reduction of pressures (Steps 3-4).
- If a measure is linked to a pressure or a state component, then the effect in Step 4 is directly estimated.

Links between existing measures and measure types are provided in Annex B.

Information needed	Data sources	Main contribution
List of measures	HELCOM Explorer HELCOM Recommendations EU MSFD Programmes of measures Other EU policies/directives International/regional conventions	ACTION project/Secretariat

Implementation status (implemented, partially implemented/ongoing, planned)	As above + EU reports on implementation of PoMs	ACTION project/Secretariat, complemented as needed by CPs
Whether a measure has an effect on activity, pressure or state	As above	Initial sorting by Secretariat/ACTION project, validation by SOM Platform

Step 2. Estimating time-lags in measure-pressure links

Even fully implemented measures do not always have an immediate effect on the state due to time lags between measures and pressures (e.g. banned substance that persists as a legacy of their production) and pressures and state (e.g. recovery of benthic communities after trawling).

Consideration of measure-pressure time-lags:

- If a measure was fully implemented by the BAU base year (2016), one needs to estimate whether there could be any time-lag deferring its effect on linked pressures beyond the base year. If no time-lag is estimated to occur, then the effects of the measure should be visible in the pressure status and the measure does not need to be included in the SOM analyses. Otherwise, the measure is included.
- If a measure is only partially implemented or planned to be implemented, then the measure is included in the SOM analysis, and an assumption is made that full implementation, including full effect on effected pressures, will take place by the end year of the SOM analysis (2030) (cf. the urge by Ministerial Declaration 2018 to implement the BSAP).

Estimation of time lags in the effect of measures on pressures has been integrated into the compilation of measures lists (Step 1). SOM Topic Teams have reviewed and supplemented the time lag data following responses from the Contracting Parties. Contribution has also been requested from HELCOM expert networks as needed.

Consideration of pressure-state time lags is presented in Step 8.

Information needed	**Data sources**	**Main contribution**
Data on time lags of effect of measures on pressures	Literature	Input from the ACTION project

Step 3. Identifying main pathways for pressures using activity-pressure-linkages

Assessing the effects of measures means describing how they affect pressures or state either directly or via activities. Thus, the links between activities and pressures need to be identified and quantified. Information on the linkages between activities and pressures is available, for instance, in the activity-pressure matrix of the TAPAS project, and in more detail in similar matrices of the DEVOTES project. These have been used as a starting point to identify the main linkages between activities and pressures.

A key issue is that the links should be (semi)quantitative and, thus allow the relative contribution of the activities to the pressures to be assessed. This is important for evaluating the proportion of the pressure reduction attributable to each activity and for providing supporting information for identifying potential new measures. The main data source for the activity-pressure linkages are expert surveys and, for some topics, existing databases. Experts are asked to estimate the most likely contribution of relevant activities to specific pressures, as well as the lower and upper bounds of contribution for each relevant activity.

Information needed	Data sources	Main contribution
Links between activities and pressures	HELCOM TAPAS linkage matrices	ACTION project
Information on relative contribution to pressures from different activities	HELCOM reports, AquaNIS database,	Input from SOM Topic teams[Error! Bookmark not defined.], ACTION project
	Expert-based evaluation	Survey participation by SOM Topic teams, ACTION project, HELCOM Expert Networks, Experts Groups, Working Groups

Step 4. Estimating the effects of measure types

Step 4 entails estimating how much a measure type will reduce a pressure from an activity. In the case of restoration measures, this step assesses how much a measure type will affect the state components. The information on the effectiveness of measure types is collected using both expert surveys and literature reviews.

The total effect of measures includes the effect of reduction in pressures on state and the direct effect on state.

4a. Relative effectiveness. Expert surveys on the effectiveness of measure types have been carried out with online surveys. The survey development was informed by SOM topic teams and several physical SOM topic workshops, as well as by the SOM Platform. The surveys asked experts to evaluate the effectiveness of measure types in reducing a pressure from a specific activity on a relative scale (no effect – highest effect), together with level of certainty of the effectiveness estimate. Figure 4 shows the general format of the survey question. As several activities can contribute to the same pressure, the survey had several questions for a pressure and hence was limited to the main activities linked to the pressure (based on Step 3 on the activity-pressure linkages). The surveys were implemented using the Webropol software.

In your expert opinion, what is the relative effectiveness of each of the following measure types in reducing A PRESSURE from AN ACTIVITY, and what is the certainty of the effectiveness of each measure type?

To answer, mark one measure in the list, then click at the position in the grid where you want place it. You can adjust the position of already entered points by moving them within the grid. Begin by placing the measure type with the highest effect on the far right of the horizontal axis and continue with the remaining measure types as appropriate.

- ○ **Measure type 1**
- ○ **Measure type 2**
- ○ **Measure type 3**
- ○ **Measure type 4**
- ○ **Measure type 5**
- ○ **Measure type 6**
- ○ **…**

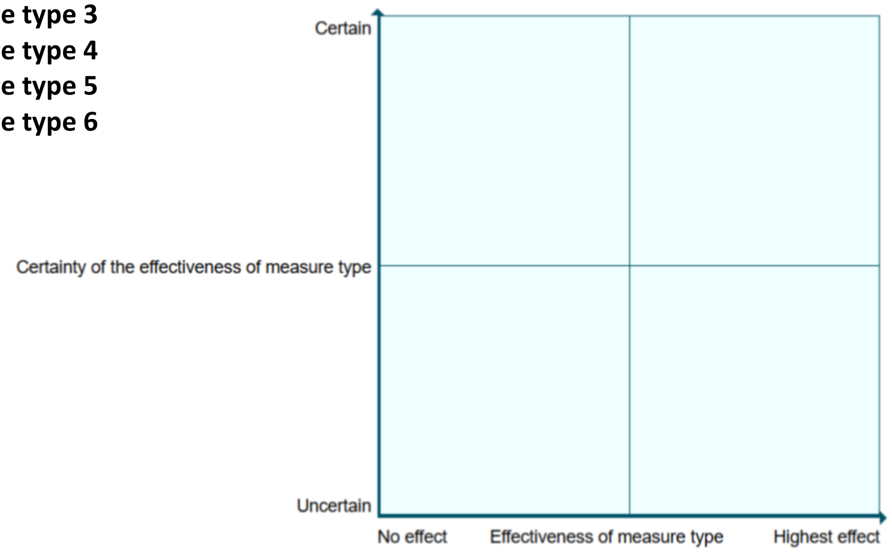


Figure 4. Question on the (relative) effectiveness of measure types in reducing a pressure from an activity and the certainty of the effectiveness. Effectiveness of measure types is estimated on the horizontal axis and the level of certainty on the vertical axis.

4b. Percent effectiveness. The pressure reduction in Step 4a is estimated on a relative scale and this needs to be transformed into percent (%) reduction. Therefore, the survey also included a second question asking the experts how much the most effective measure type is expected to reduce the pressure from the given activity (see Figure 5). This estimate was requested using a sliding bar with a range from 0% to 100%. Asking for the percent effectiveness of the most effective measure type is sufficient as it gives a reference point to the relative effectiveness scale (Step 4a) and thus allows for calculating the effectiveness of other measure types. The certainty assessment in the question in 4a (Figure 1) is used to produce expert-specific distributions for the percent effectiveness of each measure type (see Section 15 in Part III for details).

4c. Literature on effectiveness of measures. Information on the effectiveness of measures can also be found from existing literature, models and project outputs. This information has been gathered and can be used in the analysis alongside the expert-based estimates.

4d. Integration. Information on the effectiveness of measure types is used to assess the effect of existing measures on reducing pressures, using the linkages made in Step 1. Pressure reductions from existing measures can be summed to assess the total pressure reduction, but this reduction is still specific to one activity. Based on Step 3, the activity-pressures contributions (%) are used to integrate all the pressure reductions. This is the final estimate of total pressure reductions from existing measures which can be used to (i) compare against pressure targets (e.g. nutrient reduction targets) or (ii) which is used in Step 6.

The integration is further described in Part III.

Think of the measure type you rated as the most effective in the previous question. In your expert opinion, how much can the most effective measure type reduce A PRESSURE from AN ACTIVITY?

Provide your answer as a percent reduction. 100% means that the measure type will eliminate the specific pressure from this specific activity; 0% means the measure has no effect. The most effective measure type is the measure type furthest on the right in the previous question. When answering, assess measure effectiveness in areas where the measure could reasonably be implemented.

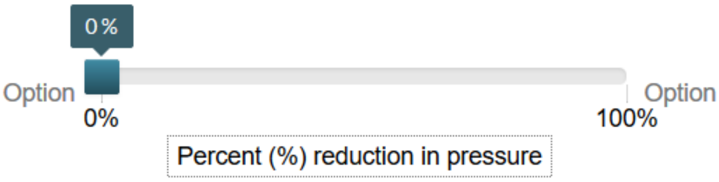


Figure 5. Question on the effectiveness of the most effective measure type in reducing pressure from an activity

Information needed	Data sources	Main contribution
Data on effects of measures	Expert evaluation	HELCOM Working Groups, Expert Groups, nominated experts
	Existing literature, studies and models	ACTION project, Secretariat, SOM topic teams

Step 5. Projected development of human activities

The other component affecting the future environmental BAU state in addition to existing measures is the possible (external) change in activities due to changes in human behaviour in the time frame of the SOM analysis. This may counteract or complement the effect of existing measures. Changes in human activities will lead to changes in those pressures that they contribute to, and the magnitude of change depends on the relative contribution of the activity to the pressure. If the extent of an activity increases, this will increase the linked pressures and may hence affect the environmental state negatively, increasing the gap to good environmental status. The extent of activities may also diminish, which would then decrease the related pressures, offering potential for progress towards GES.

The projected changes in human activities in the time frame of the analysis are included as additional scenarios that affect pressures besides existing measures. Changes in human activities are incorporated in the SOM model before the effect of existing measures, so that the effects of measures act directly on the increased or decreased activities under these scenarios. As this component can be considered external to the rest of the SOM model framework, the BAU state can be developed for several alternative assumptions related to the change in activities over time, for example 1) no change, 2) low change, 3) moderate (most likely) change, and 4) high change in the activities. This enables how the scenario son future changes in activities affects the BAU state to be evaluated. Information on the contribution of activities to pressures (from step 3 in the SOM analysis) is used to assess how the changes in activities affect the pressures.

The assessment includes the following stages:

5a. Collecting available data on the future development of human activities in the Baltic Sea region.

5b. Preparing projections of the future development of activities, including quantitative (e.g. percent) changes in the activities;

5c. Assessing expected changes in pressures due to the future development of activities, using information on the contribution of activities to pressures (SOM step 3);

5d. Assessing the effect of different scenarios on the change in human activities on the BAU state, taking into account the future development of activities and resulting changes in pressures and further environmental state (Step 6).

The analysis is limited to predominant activities in the Baltic Sea region, which include agriculture, forestry, waste waters, (commercial) fish and shellfish harvesting, aquaculture, renewable energy production, tourism and leisure activities, transport shipping and transport infrastructure.

The timeframe for the BAU in the SOM analysis stretches from 2015 to 2030. The year 2030 is the most commonly used timeframe for mid-term projections on human activities in the collected information. Since the assessment on future development of activities is primarily based on this information, the timeframe for the assessment is from 2016 until 2030.

The collected information on the future development of human activities generally includes assessments for the whole Baltic Sea region and projections for individual countries (national future development trends of activities). There is very limited information on future development of activities on the sub-basin scale (available mainly for the Gulf of Finland). Thus, the collected information allows quantitative estimates of changes in human activities for the whole sea region to be developed. Preparation of quantitative sub-basin scale estimates would require, for most of the activities, significant additional work in the form of extensive input from experts with detailed national knowledge. Thus, the projections on human activities are made on the Baltic Sea level.

Information needed	Data sources	Main contribution
Information on the future development of activities (qualitative/quantitative)	Literature, sectorial future outlook reports Project outputs (e.g. BONUS) National data (e.g. on EU MSFD Initial Assessments, and MSPD)	Secretariat, ACTION project
Converting the information into numerical values	Existing information, expert review	ACTION project, Secretariat, SOM Platform

Constructing the scenarios and addressing uncertainties

For use in the SOM analysis, the data on the development of human activities has been transformed into a quantitative format, i.e. in percent change in the activity until the year 2030. Such information is available for some activities on the sea region scale, including agriculture, forestry, transport shipping, transport infrastructure, tourism and leisure and offshore windfarms. For fish and shellfish harvesting and aquaculture, the qualitative information on future development was converted into percentages using past trends, i.e. the scale of changes in the last 10-20 years. For wastewater treatment and disposal, predicted development of underlying factors were used as an indicator for the future development of the activity.

The scenarios of future development of human activities are defined following the guidelines developed in the HELCOM SPICE project (HELCOM 2018b). According to these guidelines, it is recommended that when uncertainties are high, probabilities or sensitivity analysis is applied, alternative scenarios of possible future development are constructed, and the most likely scenario is indicated.

The main reasons for uncertainties are related to:

1. General uncertainty on the future development of activities,
2. Uncertainty on the quantitative estimates derived based on the information from literature and national assessments, including when various information sources provide different (even contradicting) estimates on future development,
3. Variation in future development trends of activities across geographic areas of the Baltic Sea.

The used approach addresses reasons 1 and 2 above when preparing the quantitative estimates on the future development of human activities for the sea region. Reason 3 is, in most cases, included in the projections of the development of human activities used as source material for the scenarios. However, it is not explicitly covered here as the scenarios are made for the entire Baltic Sea region. Three to four alternative scenarios are constructed for each activity to cover the whole range of likely future changes. These include 1) no change, 2) small change (either small increase or probable decrease), 3) moderate/most likely change and 4) large change (large increase or probable increase) scenarios. There are normally four alternative scenarios, but when the “no change” scenario coincides with the "most likely" change there are three scenarios, and small scenario means a decrease and large scenario an increase in the activity. These scenarios can be applied in the SOM analysis to draw conclusions on how the different assumptions affect the results of the analysis.

The scenarios are specified in terms of percent (%) change in the activity until 2030 compared to the current situation (in most cases year 2016). When utilising the available information, greater emphasis is given to regional information sources and mid-term projections (ending around 2030) and lower emphasis to national and long-term projections. Qualitative national level data have not been used to define quantitative scenarios, but rather to check the validity of the regional data. The quantitative scenarios are based on regional projections, with the exception of fishing and aquaculture, for which past development has been used, and urban sewage water systems (wastewaters), for which projections on population development, urbanization and connectivity to wastewater collection systems were used.

A no change scenario is included for all activities and always implies a 0% change in the activity by 2030. In cases where no changes in the activity are predicted by 2030 or the direction of the change is not clear, "no change" depicts the most likely scenario and alternative scenarios are developed for a decrease and an increase in the activity. The negative scenario is formulated in terms of a probable decrease and the positive scenario in terms of a probable increase in the activity.

In cases where change is expected and there is no ambiguity in the direction of the change (activity either increases or decreases), small and large change scenarios are developed to capture the likely range of the change of the activity, and the moderate scenario depicts the most likely expected change in the activity until 2030. Small change is generally determined based on the smallest probable change reported in the source studies, while large change is determined based on the largest probable change in the source studies.

Based on the gathered data, it was not possible to select the most likely scenario for two of the activities (marine aquaculture, wastewaters). As the SOM model should be run for the most likely change in human activities until 2030, the moderate change scenario will be used as a proxy for the most likely change for these two activities.

It should be noted that the current situation with COVID-19 and its possible implications on the development of human activities is not reflected in the assessment, as there is no information on the long-term effects it may have on the economy or activities. The current situation poses a challenge for assessing the most likely scenarios for human activities, which has been done based on currently available information.

Incorporating the development of human activities in the SOM analysis

The projected development of human activities within the timeframe of the SOM analysis are run as additional scenarios in the SOM model to i.e. generate independent results to compare with the default (most likely) results. The projected developments in activities are incorporated in the model before the effects of existing measures on pressures, so that the measures can also impact increased or decreased activities when the analytical model is run. Thus, this component can be seen as 'additive' to the main SOM framework, and several SOM model runs with alternative scenarios on the development of activities are possible.

The scenarios on the projected development of activities affect the extent of activities and they are expressed in terms of percent changes in the activities. This corresponds to the general format of the SOM model and enables the inclusion of the data in the model. Using information on activity-pressure contributions (Step 3 in the SOM analysis), the changes in activities can be translated into changes in pressures, and further to environmental state. This is how the projections of activities are incorporated in the model.

Different scenarios can be formulated based on assumptions about future change in activities. In the scenarios, all activities change in a similar manner. Two primary scenarios are 1) no change and 2) most likely change in activities. In the no change scenario, all activities remain at their present (or year 2016) level. In the most likely change scenario, all activities change according to the most likely projection based on the compiled data, or in cases when it has not been possible to assess the most likely projection, according to the moderate increase scenario. In addition, it is possible to run additional 3) small/negative change and 4) large/positive change scenarios in the SOM model. Different scenarios can therefore highlight whether changes in activities affect the overall results of the SOM analysis.

Step 6. Linking reduced pressures with state components

The SOM analysis is structured using the same major pressure themes and biodiversity components as in the State of the Baltic Sea report (HOLAS II) and other HELCOM agreements. The methodology for the SOM analysis is adaptable to cover both topics with and without established GES threshold values or pressure targets. Step 6 is only relevant for the topics for which the analysis extends until environmental state, i.e. birds, mammals, fish, benthic habitats and hazardous substances.

Information on the pressure-state linkages has been collected with expert surveys.

6a. Identifying significant pressures. In the surveys, experts were first asked to identify 3-6 significant pressures affecting the state component in question. The pressure ranking was done on a relative scale (Figure 6) which allows for estimating the contributions of the pressures to the state component.

6b. Needed pressure reduction. After the ranking, the survey asked by how much all significant pressures need to be reduced in order to achieve state improvements, regardless of the time it takes. The survey asked for the minimum, most likely and maximum reduction required (Figure 7).

This information enables the probability to reach GES or specific state improvements to be assessed, given that the pressures are reduced by the amount estimated in Step 4.

The exact approach in Step 6 depends on whether the topic is described in terms of pressures or state, and on the existence of an agreed GES threshold value as follows:

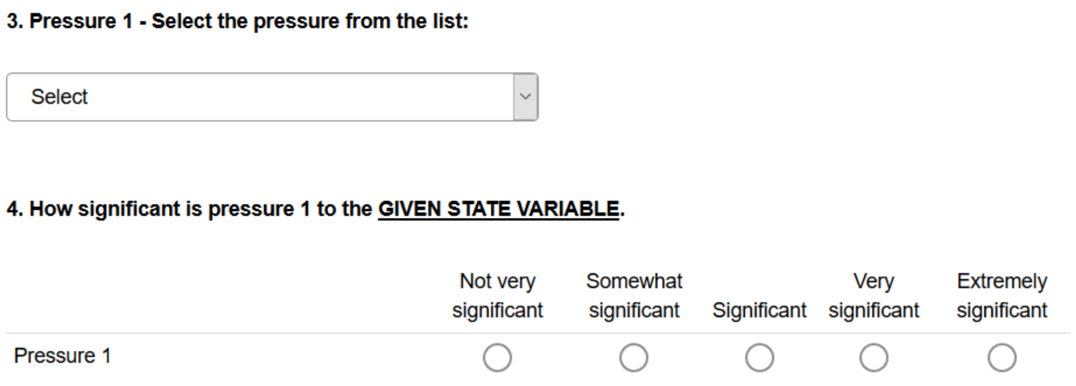
- When a pressure reduction target exists or the indicator is defined in terms of pressures, the evaluation stops at the pressure component and environmental state is not evaluated in the SOM analysis. Thus, the analysis is based on pressure reductions. This is the case for eutrophication, non-indigenous species, marine litter and underwater noise. However, the pressure-state time-lags are included in the final considerations.

- When a GES threshold exists, the experts were asked how much all significant pressures need to be reduced to achieve GES. From these it is possible to define a cumulative distribution for required pressure reduction that represents the probability to reach GES for a given reduction in significant pressures. Thus, the gap to GES can be defined as a probability of not reaching GES for expected reduction in significant pressures resulting due to existing measures, or based on percentiles of the pressure reduction distributions, and an improvement in state can be defined as an increase in the probability to achieve GES. The gap can also be presented as a required additional reduction in total pressure (consisting of significant pressures) to achieve GES with 100% probability. However, this reduction applies to a combined pressure that can consist of multiple pressures of varying significance from different basins.
- When a GES threshold does not exist, the experts were asked how much all significant pressures need to be reduced in order to reach a specific state improvement (in %), or how much pressures need to be reduced to reach a noticeable improvement in state (benthic habitats). These, in combination with estimated pressure reductions resulting from existing measures, can be used to assess the expected scale of improvement in state.

Information needed	**Data sources**	**Main contribution**
Spatial data on pressures and impacts	HELCOM map and data service	Secretariat
Spatial data on state components	HELCOM reports, ICES stock reports	Secretariat
Identifying significant pressures	Expert evaluation	Working Groups, Expert Groups, nominated experts
Responses of state components to changes in pressures	Expert evaluation	Working Groups, Expert Groups, nominated experts

In your expert opinion, what are the most significant human-induced pressures to the <u>GIVEN STATE VARIABLE</u>?

Choose three (3) to six (6) pressures from the drop-down menus and rate their significance. Significance covers the intensity of the pressure, sensitivity of the state component to the pressure and geographic extent of the pressure.


3. Pressure 1 - Select the pressure from the list:

4. How significant is pressure 1 to the GIVEN STATE VARIABLE.

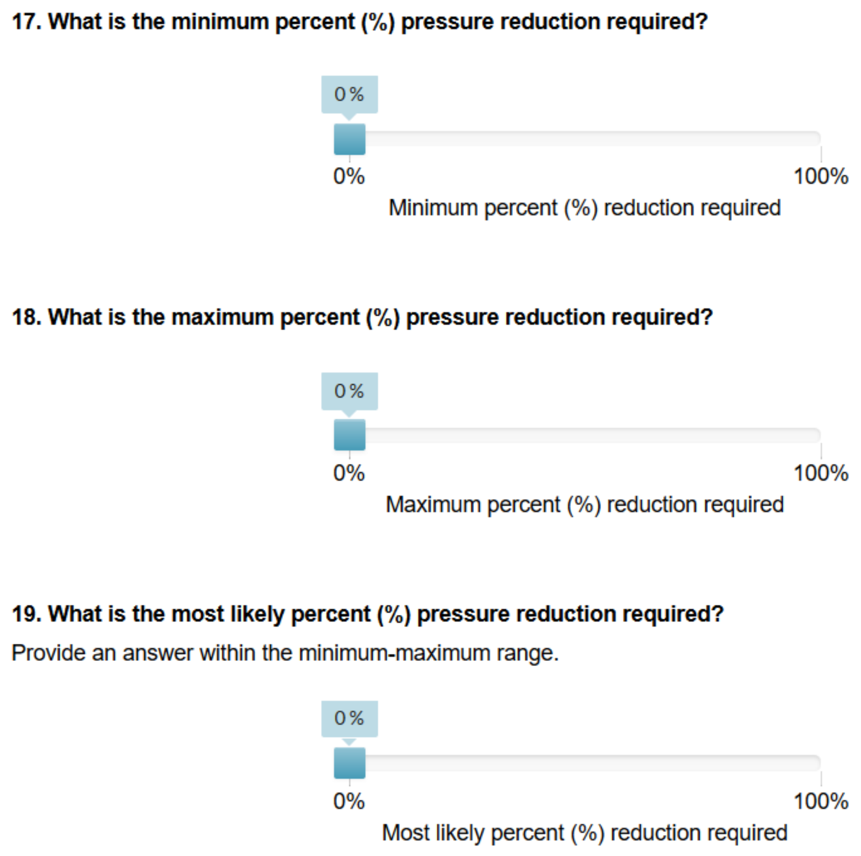
	Not very significant	Somewhat significant	Significant	Very significant	Extremely significant
Pressure 1	○	○	○	○	○

Figure 6. Question to identify the most significant pressures affecting the state variable

Consider all the pressures you selected in the previous questions. In your expert opinion, by what percentage do these pressures need to be reduced in order to achieve or maintain a good state for the <u>GIVEN STATE VARIABLE</u>, regardless of the time it takes?

Base this assessment on the HELCOM core indicator INDICATOR NAME where good state is GOOD STATE. Current state is CURRENT STATE, i.e. the state is STATUS.

Please estimate the minimum, maximum and the most likely percent (%) reduction in pressures required to achieve or maintain a good state.


17. What is the minimum percent (%) pressure reduction required?

18. What is the maximum percent (%) pressure reduction required?

19. What is the most likely percent (%) pressure reduction required?

Provide an answer within the minimum-maximum range.

Figure 7. Question on the required pressures reductions to achieve state improvements to define three-point estimates to assess the linkage between total pressure and state. This version is for cases where there is an agreed GES threshold value

Step 7. Assessing sufficiency of measures and gaps to good environmental status

When the BAU state (future state with existing measures and projected changes in human activities) has been developed, it is compared with GES to identify whether there is a gap and new measures are needed. The total effect of measures on state is calculated as the reduction of the GES gap resulting from reductions in pressures based on the previous steps. This reduction is measured as an increase in the probability of reaching GES for different topics and state components. The probabilistic approach further enables an extensive analysis of uncertainties and risks related to the outcomes of the analysis. In addition to existing measures, the Step 5 results (projected development in human activities) also affects the outcome of the SOM analysis. If a pressure is predicted to increase and no measures are in place to control that pressure, the gap to GES may increase.

Step 8. Time lags in state recovery

Reductions in pressures during the BAU period do not necessarily mean that the state will become good by 2030. The lags in state recovery, which may result for multiple reasons, are identified in the ACTION project or as part of the pressure-state expert surveys.

In the context of the SOM analysis, the issue with time lags is resolved by focusing on pressure reductions and their possible effect on state (even if the state recovery takes place much later).

Pressure-state time lags are not explicitly included in the SOM analysis, but instead evaluated as additional information alongside GES threshold values in Step 7. They will affect the interpretation of the SOM results and are important to consider as part of the broader overview. By separating pressure-state time lags from the analysis, the effect of measures can be separated from less governable time lags (e.g. population growth) and allow for the consideration of the sufficiency of measures in the case of avoidable time-lags (i.e. if, for example, the topic is projected to eventually reach GES with existing measures and projected development of human activities, but GES could be reached sooner if additional measures were implemented). Additionally, topics where the defining feature is a very large pressure-state time lag (e.g. eutrophication) are only evaluated to the level of pressures in the SOM analysis, as it is already known that GES will not be achieved by the end year 2030.

Information on the time lags has been collected with the expert surveys on pressure-state linkages. The formulation of the question depends on the existence of a GES threshold value and the topic of the survey. Figure 8 presents an example of the time lag question for state components with a GES threshold.

Assume sufficient measures are implemented to achieve GES for the GIVEN STATE VARIABLE in an infinite time horizon. How long will it take to achieve GES?
Consider all possible time lags between changes in pressures and changes in the state variable when answering.

- 0 years (no time lag)
- 0-5 years
- 6-10 years
- 11-25 years
- 26-50 years
- 51-100 years
- More than 100 years

Figure 8. Time lag question in the pressure-state surveys

4. Assumptions, simplifications and benefits of the SOM approach

This section discusses the assumptions and simplifications of the approach for the SOM analysis and what kind of implications they may have on the results, as well as describes the benefits of the approach. Due to the geographic and thematic coverage of the SOM analysis, as well as data availability across the region and topics, several assumptions and simplifications have been necessary. However, the generalized and comparable approach also brings about benefits and the analytical model can accommodate model and literature-based data as it becomes available.

Assumptions

Several assumptions have been made in SOM analysis, and the most significant are described here. The main assumptions are related to the information about and implementation of existing measures, and their spatial coverage.

One of the major assumptions in the approach is that (i) **all existing measures will be implemented by the end year of the SOM analysis**, i.e. by 2030, and (ii) **all existing measures will have sufficient time to influence pressure reductions**. This assumes full and early implementation of the measures across the region, and although this may not necessarily be the case for every measure once enacted, the assumption is required as the aim of the SOM analysis is to assess the pressure reduction from existing measures, and it is infeasible to predict the likelihood of implementing each existing measure separately. However, it is therefore important to keep in mind that unless the full array of existing measures is implemented in the time frame of the analysis, the SOM analysis can potentially project larger pressure reductions than will actually take place.

The SOM approach relies on **information on existing measures and their implementation status** communicated to the Secretariat through either normal reporting procedures, such as HELCOM Explorer, or the SOM measures data call made during summer/autumn 2019. Resources do not exist to obtain more detailed information on measure implementation status or other measure details, e.g. from EU MSFD reporting or other national sources. Incomplete reporting of existing measures may cause an overestimation of the need for new measures.

The **spatial coverage of a measure** encompasses all the marine areas in countries where it is implemented, unless there is more specific data on the spatial coverage of the measure. Total effects on sub-basins/spatial units are estimated using spatial weighting, based on the proportion of national marine areas to the total areas of the sub-basins.

Additional assumptions specific to the SOM approach and model and explanations of what they mean for the interpretation of the results are presented below. The SOM model is presented in detail in Part III.

Joint impacts, overlaps and additivity of the effectiveness of measure types: The SOM model is based on the additivity of pressure reductions from measure types, i.e. effects of measure types in reducing pressures are summed together. In order to avoid overestimating pressure reductions, the model takes into account the overlaps across measure types and the chain effects resulting from the pressure reductions from other measures, as a measure can only impact the pressure share that remains after the preceding measures have been incorporated. Other joint impacts (synergistic/antagonistic) are not included, as knowledge of these is incomplete for the majority of the pressures. See section 14 on more detailed information on joint impacts.

Estimating the effectiveness of measures: Due to the structure of the effectiveness of measures survey, measure type effectiveness is highly influenced by the expert estimation on the percent effectiveness of the most effective measure type for any of the activity-pressure pairs. Thus, under- or overestimation of the effectiveness of the most effective measure type affects the effectiveness of all other measures in that activity-pressure pairing. This needs to be acknowledged when interpreting the results.

Geographical variability: The spatial resolution varies across the topics and also for the data components within a topic in the SOM analysis. This is due to the relevant scales of the pressures and activities and the data availability. Though always based on the 17 HELCOM sub-basins, specific data uses spatial resolution ranging from the entire Baltic Sea to all 17 sub-basins. This variation may cause some disaggregation inconsistencies in the results. These are mainly related to the reliability of the information on the implementation area of existing measures (i.e. is the spatial extent of implementation of existing measures reported correctly) and on the contribution of activities to pressures (i.e. are the activity-pressure contributions correct for all areas). To account for the differences in spatial resolution, the spatial scale for reporting the results varies across and within topics according to the spatial scale of the underlying data.

The number and country of experts assessing activity-pressure contributions, measure type effectiveness and pressure-state linkages in the expert surveys: The number of experts who have provided responses in the SOM expert surveys varies across questions and topics, as does the amount of literature data for the effectiveness of measures across measure types and topics. Further, there are differences in the regional coverage of the expert evaluations, as responses may be missing from some countries. Thus, the amount of data for the different components of the SOM model varies, and transparency is needed when presenting and interpreting the results. Criteria depending on the number of expert responses have been established which determine whether the results are presented in a quantitative or semi-quantitative/qualitative format or excluded.

Weighting of group answers: The survey responses where multiple experts have contributed are given a higher weight, if the experts have stated they could have each provided an individual response. It is, however, possible that the responses could have been slightly different if these experts had responded individually.

Use and definitions of measure types: To make the SOM analysis feasible, individual measures were grouped into measure types and the effectiveness of these measure types is the main input data to the SOM model. This process allows for broad but also closely aligned, yet different, national or regional measures to be addressed together. However, descriptions of measure types are broader than the measures behind them and therefore the effectiveness estimates become less specific. This may result either in over- or underestimating the effectiveness of existing measures. However, it is worth noting that many of the individual existing measures are also broadly defined (e.g. HELCOM recommendations).

Probability distribution types used in the mathematical analysis: In principal, a modified beta-distribution (PERT distribution) was applied in the SOM model to the three-point estimates derived from the expert survey responses and other data sources. The parametrization of this distribution affects the probabilities assigned to the most likely, minimum and maximum values. This is reflected in the results.

Definition of total pressure reductions for state variables: The total pressure reductions for state components are calculated as weighed sums of reductions in significant pressures, where spatial shares and significance of the pressures to the state component are used as weights. This implies partial substitutability of pressure reductions across pressures and allows an increase in the probability to achieve status improvements even if not all significant pressures are reduced.

Derived values for the most likely, minimum and maximum effectiveness of measure types from the expert survey responses: Unlike for the activity-pressure contributions and pressure-state linkages, the three point values for the measure type effectiveness are derived from the percent effectiveness of the most effective measure type and the relative effectiveness of the measure types and the certainty of that effectiveness. This results in an additional step between the expert responses and SOM model to calculate the percent effectiveness of the measure types and requires an assumption on defining the minimum and maximum values based on the certainty estimates.

Generalizations and simplifications

The SOM model covers the majority of human activities and pressures and the HOLAS II state components and attempts to capture all relevant measures in place in the Baltic Sea (regional and national). This means that the model is more extensive than any previous model in this field and, hence, requires some generalizations/simplifications.

Standard relative working units. Due to the wide coverage of measures, activities, pressures and state components, the analysis specifies the linkages between the elements in terms of percent changes. This applies for all linkages, i.e. the contribution of activities to pressures, the effects of measures on pressures and the changes in state components due to changes in pressures are estimated as percent changes. This also allows the comparison of results across topics. The results can support identifying where and what type of measures are potentially effective, taking into account that measures can affect multiple pressures and state variables.

Measure types instead of individual measures. It is infeasible to analyse individually the effects of hundreds of existing measures in the Baltic Sea region (including localised or national measures) in the time allocated to the SOM analysis. To simplify the catalogue of measures, the SOM approach groups individual measures to ‘measure types’ which aim to capture the main elements of the measures but still remain at a relatively broad or more abstract level. This has the limitation that the measure types and individual existing measures are not equal (i.e. the former are abstractions and the latter are closer to reality). In a hypothetical example, a measure type such as ‘apply pingers in gillnet fisheries to reduce bycatch of harbour porpoise’ does not say how many pingers are being used in gillnets, how widely this is applied in different parts of the Baltic, if this is enforced, or how frequently this requirement is not followed. However, a probabilistic approach is used to assess the effectiveness of measure types, which allows for uncertainty and can capture variation in the effectiveness due to abstractions and to spatial differences. To assess the effects of existing measures in reducing pressures, the existing measures are linked to the measure types and used in the SOM model at a later stage (see Steps 1 and 4).

Relative scale of effectiveness of measures. The effectiveness of measure types is assessed using a relative scale (no effect-highest effect). Estimating the relative effectiveness of a measure type allows for ordering the effectiveness of measure types in reducing pressures from certain activities or in improving certain state components, and also provide a data set applicable to the inclusion of new measures at any point in the process.

To transform the survey responses to the percent (%) scale, the expert surveys ask how much the most effective measure type can reduce a pressure in percent (see Step 4). The percent effectiveness of each measure type is calculated using the percent effectiveness of the most effective measure type and the relative effectiveness of the rest of measure types. The total effects of measure types on pressures are calculated by summing the effects of individual measure types on pressures, taking joint effects into consideration. The individual percent impact of a measure type depends on the effectiveness of a measure type, activity-pressure contributions and the spatial coverage of a measure type.

Pressure–state linkage. Dependency of state on pressures is the basic assumption in environmental science. In reality, many of these links have not been established in a quantitative way. In the SOM analysis, the pressure-state link is therefore based on expert evaluation (Step 6).)

Scope of the analysis. Comparisons of the (economic) effectiveness of pressure reductions across topics (e.g. 5% reduction in input of nutrients and 5% reduction in input of litter) requires information on both the cost and benefits of the measures and is not in the scope of the SOM analysis. Cost-effectiveness on measures is assessed in ACTION Work Package 6.2, but this does not include an assessment of the benefits.

General. The SOM analysis does not give the final answer with a single value representative of the general sufficiency of measures, but instead the outputs must be interpreted considering the assumptions, rationalisations, and potential limitations described above. The benefits of the model use are, however, numerous.

Benefits

The sections above described assumptions, simplifications and limitations to make the analysis feasible. These are important to keep in mind when interpreting the outputs from the SOM analysis. The following section addresses the benefits of the approach and analysis outputs.

Use of effectiveness estimates for new measures. As the measure types are not overly specific, it is possible to use them for estimating the effectiveness of the new measures. This can be done in two ways: (i) if a measure is considered new but still falls under the description of the measure type, its effectiveness can be deduced based on the effectiveness of the measure type in the SOM analysis, or (ii) if the new measure is between two measure types, its effectiveness can be placed between the effectiveness of the two related types in the SOM analysis.

Use of pressure-state linkage. The pressure-state linkage is a precondition for many environmental analyses and tools, and it is not very often addressed in marine assessments. The expert-based suggestions for these linkages (with uncertainty ranges) can be later validated by specific data and (if found adequate) used for further analyses.

Steps forward in the integrated assessment of the marine environment. The development of methods and results that provide such extensive interlinkages represents a considerable progress in interdisciplinary research related to linking measures, activities, pressures and environmental state. This greatly improves the description of linkages between the socio-economic system and ecosystem. The progress includes both conceptual and operational aspects, including the development of the SOM approach and model and collecting data for it. The approach is flexible enough to be adapted to other data sources once available.

Providing information for further analyses. Many of the approaches and results can be used in further analyses of the Baltic Sea environment, including the linkage framework, business-as-usual (BAU) state developed within the SOM analysis, and effects of measures. For example, the BAU state is required for assessing the cost of degradation and economic benefits from achieving GES of the marine environment.

Flexibility and updating of the model. The SOM model is flexible in the sense that it can include information from literature, studies and models and expert elicitation. The SOM model is thus sufficiently malleable to accommodate different types of data, harmonising the data types via the assessment structure, and thereby allowing it to be applied in more broad and general terms or in a highly specific manner, as required. In addition, the model can be updated when new information becomes available. The overall approach is general and is applicable in other contexts.

Transparency and commensurability. In principle, the SOM approach is straightforward in that it does not include complex definitions of the natural environment and it applies similar activity-pressure-state linkage chains, as well as definitions for measure effectiveness and state improvements for all topics. Therefore, it allows the comparison of results across topics and transparent analysis on the linkages and interdependencies between measures, activities, pressures and state variables. This can help identify where and what type of new measures are needed.

Presentation of certainty and confidence. Certainty and confidence of the assessment are identified as part of the data collection. Most of the results are presented as distributions and probabilities, which clearly show the certainty of the assessment (i.e. the calculated mean/expected value, and the spread of data/responses associated with each evaluation). In addition, the experts’ own confidence in their assessment is provided together with the results. This enables the overall certainty and confidence of the assessment to be evaluated, so that the results can be correctly used to support regional and national policies and their implementation. More information on certainty and confidence is provided in Section 12.

PART II - DATA FOR THE SUFFICIENCY OF MEASURES ANALYSIS

5. Data collection

All main components of the SOM analysis have entailed the collection or compilation of existing and new data. Whenever possible, data used in the analysis have been based on existing literature, studies and models. However, a preliminary investigation on data availability identified significant gaps in published information with regard to 1) activity-pressure contributions (Step 3), 2) effectiveness of measures in reducing pressures (Step 4), and 3) pressure-state linkages (Step 6). To fill these gaps, expert elicitation was necessary to allow for the comprehensive inclusion of measures, activities, pressures and state components in the analysis.

Thus, information on activity-pressure contributions, effectiveness of measures and pressure-state linkages has been mainly collected using expert elicitation. The expert surveys to collect data for the SOM analysis were implemented in 2019 –2020. Where available, expert inputs have been complemented with information from existing literature, and a specific literature review has been conducted for the effectiveness of measures part (Step 4).

Topic-specific information about measure types, expert surveys and literature review on effectiveness of measures are available in the topic reports.

6. Existing measures

Information on existing measures (Steps 1 and 2) was compiled by the Secretariat in June – July 2019 based on available information in HELCOM reporting, EU legislation, and international conventions. The compiled measures were subsequently distributed to the Contracting Parties for review and supplementation with national measures. The compiled measures were then linked to the developed measure types to create a library of existing measure types. However, not all existing measures were necessarily linked to a measure type. This occurred when the existing measure is fully implemented and its effect on the environment is already fully realized. In this case, the existing measure does not meet the definition of a SOM existing measure (see Step 1). Occasionally, an otherwise valid measure did not sufficiently conform to one of the measure types. This step required interpretation of the measure lists submitted by Contracting Parties and, therefore, in a few cases the final overview may conflict slightly with the nationally reported information. In such cases, the comment text sent together with the implementation status was considered authoritative. Additionally, pilot projects were typically not included in the model as existing measures. The SOM Platform requested that a second round of review be undertaken following the development of measure types to allow countries to reassess their efforts in this new format. That process took place in May 2020.

7. Activity-pressure contributions

Activity-pressure linkages (Step 3) are assessed as the percent (%) contribution of activities to pressures. Quantification of these linkages has been based on either expert elicitation or existing data sources.

A data-based approach has been preferred and possible for five pressure inputs: potential loss of seabed, potential disturbance of seabed, input of nitrogen, input of phosphorus, and anthropogenic introduction of non-indigenous species.

For *potential loss and disturbance to the seabed* (benthic habitats), the approach used in HELCOM HOLAS II has been employed, which utilizes the Baltic Sea Pressure Index (BSPI) and Baltic Sea Impact Index (BSII) to integrate data reported to the Secretariat from the Contracting Parties through regular reporting and previous data calls. Detailed explanation of the methodology used to generate these data is available in Annex 1 of the Thematic assessment of cumulative impacts on the Baltic Sea 2011-2016 (HELCOM 2018d). There is close correspondence between the BSPI activity list and the SOM activity list, as both are based in methodologies developed by the HELCOM TAPAS project. However, some activities in the BSPI data set have been combined to conform to the SOM activity list. For both potential loss and potential disturbance, the potential impact from each activity in a sub-basin has been divided by the total pressure in the same sub-basin to produce sub-basin specific activity-pressure contributions.

For *anthropogenic introduction of non-indigenous species*, entries on primary introductions into the Baltic Sea were recovered from the AquaNIS database for 2005-2016. The introduction vectors listed in these entries are a close match to the standard SOM activity list. Vectors listed as 'Vessels' are assumed to be commercial transport, given the short distances recreational craft typically travel and, therefore, the low likelihood of contributing to primary introductions. The 'Vessels' vector is further divided into shipping - ballast water and shipping - biofouling and this division is adopted into the SOM analysis on NIS. AquaNIS combines land- and marine- based aquaculture and this approach was also adopted. Introductions from natural spread are listed as the result of 'Activities and sources outside the Baltic Sea region'. Additionally, several activities outside of the SOM structure contribute to introduction risk. These activities (e.g. live food trade, aquarium trade) are reflected in the data (i.e. calculations on percent contribution to invasions include these activities) but have not been included in the SOM analysis because of both their estimated small contribution to NIS introduction (below the generally applied threshold of 5% for a significant pressure in the SOM model) and their place outside of the model's structure. Where multiple potential pathways were indicated in the database, the introduction was divided equally between each activity. Additionally, some entries list a range of years that correspond to the introduction and, in this case, the introduction was equally divided across each year. In the event of lack of vector data, contributions were proportionally divided across activities based on the proportion of total introductions with known vectors.

The 12 years of data selected to generate the activity-pressure contributions were chosen to reflect the current conditions in the Baltic Sea. The time frame begins following clear changes in NIS introduction risk from aquaculture in the period leading up to EU legislation on NIS in aquaculture and ends far enough from present to reduce the likelihood of unobserved introductions. To compensate for the high volatility caused by the rare nature of introduction events, a 3-year moving average was utilized. Maximum and minimum values of the generated moving averages are used to calculate the maximum and minimum percent activity-pressure contribution values used in the SOM model. Most likely contribution values are calculated by first identifying the most common 10% contribution range (i.e. 0-10%, 10-20%, 20-30%, etc.) for each vector and then taking the average of the values in that range.

For the *input of nitrogen and phosphorus*, HELCOM ACTION WP4 developed source apportionment data based on data collected within the PLC-6 and PLC-7 projects. This data follows the so-called load-oriented approach which represent loads to the sea from each given source/sector. The year for data collection was 2017 (PLC-7) for all countries except for Sweden and Denmark where PLC-6 data, collected in 2014, was used. The data was downloaded from the PLC-water database via the PLUS interface on January 30, 2020 for the PLC-6 data and on March 31, 2020 for the PLC-7 data. In addition, the direct inputs from coastal industry and wastewater treatment, and marine aquaculture in 2017 were obtained from the PLC-water database on March 25, 2020. Atmospheric nitrogen deposition split into sectors, countries and basins for 2014 was obtained from EMEPs assessment (Bartnicki and Benedictow, 2017). There is a complete data set for all countries and basins for the direct inputs and atmospheric deposition. All countries have reported some information on the division between the source categories, but detailed attribution to sources/sectors are missing in some countries. Further, some countries only provided aggregated information on diffuse and inland point contributions. Sectoral estimates of these aggregated data have been attempted based on the following methodology.

For diffuse sources, the contribution reported as unknown from Estonia was assumed to be to equal shares comprising of scattered dwellings and stormwater/overflows. Latvia only report natural background contributions and the sum of anthropogenic contributions. Based on proportions of what was reported from Lithuania, but expecting somewhat smaller contribution from agriculture, for nitrogen it was assumed that 90% of the contribution comes from agriculture, 5% from atmospheric deposition and 2.5% each from stormwater/overflows and scattered dwellings. For phosphorus, it was assumed that 80% of the contribution comes from agriculture and 10% each from scattered dwellings and stormwater/overflows. Russia reported only agriculture, unknown and natural background. For the Gulf of Finland, the unknown input was quite high, so it was distributed by assuming the same contribution from atmospheric deposition and forestry as the sum from Sweden to Bothnian Sea and Bothnian Bay, having somewhat similar catchment size and reasonably the same catchment characteristics. Following the approximate shares for the other countries, it was further assumed that 2.5% (10% for phosphorus) of the anthropogenic losses could be attributed to scattered dwellings and stormwater/overflows. The remaining unknown losses were added to natural background.

For inland point sources, Latvia, Lithuania and Russia all reported an aggregated sum of the indirect point sources. These were distributed between industry and municipal wastewater treatment (WWTP) according to the average proportions for all the other countries (for total nitrogen 20% industry and 80% WWTP and for total phosphorus 8% industry and 92% WWTP).

Expert elicitation was used to estimate activity-pressure relationships for the following pressures: input of hazardous substances (further differentiated to mercury, PFOS, TBT and diclofenac), input of marine litter (further differentiated by top litter item), disturbance or displacement of marine mammals by human presence (further differentiated by species), disturbance or displacement of birds by human presence (further differentiated by species), input of noise (further differentiated to continuous noise 63/125 Hz, continuous noise 2 kHz, and impulsive noise with peak energy below 10 kHz). These surveys were distributed to relevant HELCOM expert bodies and/or nationally nominated SOM experts. Responses were received from experts based in individual Contracting Parties as indicated in Table 1.

The remainder of the pressures did not require detailed activity-pressure linkages, as they are either by definition single-activity pressures (e.g. extraction of fish only occurs through fishing) or are not fully analysed in the SOM model context (e.g. inland habitat loss/degradation).

Table 1. Number of experts contributing to activity-pressure surveys

Pressure	DE	DK	EE	FI	LT	LV	PL	RU	SE
Input of hazardous substances		1	1	4					
Input of marine litter	1	1	1	1			1		1
Disturbance/displacement by human presence - mammals	1	2							
Disturbance/displacement by human presence - birds							1		2
Input of underwater noise	1	1	1				2		2

8. Effectiveness of measures, pressure-state linkages, and pressure reduction data from other sources

The expert surveys on the effectiveness of measures (Step 4) and pressure-state linkages (Step 6) were developed in the autumn 2019 in collaboration between the ACTION project and the HELCOM Secretariat. Considerable input was received also from HELCOM Expert Groups and Networks, the HELCOM SOM Platform, HELCOM SOM topic teams, as well as dedicated topic workshops to support the SOM analysis. The exact process depends on the topic in question and is outlined in Table 2. Two surveys were sent out: i) effectiveness of measures and ii) pressure-state linkages.

The first versions of the general format for the effectiveness of measures and pressure-state linkages expert surveys were developed in September 2019. They were presented in the SOM Platform 2-2019 meeting, and subsequently revised, e.g. to include questions on experts' background. The surveys were then pre-tested within the HELCOM Secretariat and implemented during the first SOM topic workshops in late September (marine mammals) and early October (birds) 2019. Following feedback received in relation to these workshops, the surveys re-entered a development phase. The surveys were iteratively developed over the course of the remaining topic workshops in the fall 2019, guided by regional experts attending, with revisions made after each workshop to both the general structure and topic-specific contents of the surveys. For the topics not having specific SOM workshops, the survey structures were developed in collaboration with the topic teams or other topic experts. The general versions of the effectiveness of measures and pressure-state surveys were ready in November 2019, and the topic-specific surveys were finalized and sent out to relevant experts in December 2019 or January 2020, depending on the topic.

Table 2. Parties contributing to the structural development of SOM topics and/or surveys

Topic	Topic team lead	Workshop	Other groups with significant contributions
Hazardous substances	Denmark, Sweden	SOM-HZ WS 1-2019	EN HZ
Marine litter	Estonia	-	EN Litter
Underwater noise	Denmark	-	EN Noise
Benthic habitats	-	EN BENTHIC 3-2019	EN Benthic, ACTION WP2
Migratory fish	Finland	SOM-FISH WS 1-2019	
Coastal and commercial fish	Sweden	SOM-FISH WS 1-2019	
Marine mammals	-	SOM Bio-MM WS1	
Birds	-	SOM-Birds WS 1-2019	Ad hoc support from Germany and Sweden
NIS	Secretariat	-	
Nutrients	-	-	ACTION WP4, Agri Group

The overall structure of the expert surveys and questions within it were similar across topics, but topic-specific adjustments were made whenever needed. For example, for marine litter, a litter item-based approach was developed to better reflect the topic's regulatory framework. For benthic habitats and harbour porpoise, the state improvement was depicted in terms of a qualitative improvement specifying a noticeable improvement in state, rather than the quantitative (percent) changes in state components used for the other topics.

The expert surveys were implemented using an online survey tool, Webropol. The invitations to the surveys were sent via email to the nominated experts, followed by two reminders. The structure of both surveys was similar. The opening part of each survey introduced the specific topic, together with instructions for answering and contact information in case of questions. The following sections second part included the main questions, followed by supporting questions on the background of the respondent(s). Both surveys included questions on the experts' own evaluation of their confidence in the response(s) they provided. The survey platform allowed for saving responses and continuing later, prior to submission of finalized surveys. The surveys also collected background information on respondents' field of expertise and how long they have been in that field.

The pressure-state linkages surveys were implemented in December 2019 – February 2020. The effectiveness of measures surveys were carried out in two rounds due to a survey software problem which necessitated respondents to review and complement their original answers. The first round was implemented in December 2019 – February 2020 and the second round in April – May 2020, based on specifically identified gaps per response. The invitations to the surveys on benthic habitats, birds, mammals, fish, hazardous substances and non-indigenous species were sent in December 2019. Invitations to the litter, noise and nutrient runoff from agriculture survey were sent in January 2020.

As the purpose of the SOM analysis is to support the HELCOM Baltic Sea Action Plan update, the identification of experts to respond to the surveys relied on existing HELCOM structures and expertise. The expert pool was formed from the representatives of the relevant HELCOM Expert Networks and Groups, as well as any additional experts nominated by Contracting Parties (i.e. via HELCOM Working Group and SOM Platform contacts) specifically for the task. Altogether, 475 individual experts were identified as potential respondents to the surveys, with 35-114 experts per topic. Note that some were identified/nominated as experts to respond to multiple topics, and thus the total size of the expert pool across all topics was 512 experts.

Table 3 shows the number of contributing experts per survey and country. As group responses were allowed, one survey response may be the collaborative effort of several experts. Table 4, at the end of this section, shows the number of responses per sub-topic, taking into consideration the contribution of each expert in case of group responses.

It is worth noting that responses may not be complete: experts may have only provided answers to one or a few specific sections or questions of the survey, e.g. specific areas, species or measure types. Additionally, a lack of responses to a topic by a country should not be necessarily be interpreted as lack of engagement in the process. Several nominated experts acknowledged the survey and declined to participate citing methodological or data use concerns.

Table 3. Number of experts contributing to surveys on effectiveness of measures (EoM) and pressure-state linkages (P-S)

Survey	DE	DK	EE	FI	LT	LV	PL	RU	SE	Total
Benthic habitats EoM	7	4	-	3	2	-	-	2	4	22
Benthic habitats P-S	7	4	-	4	1	1	-	-	2	19
Birds EoM	2	5	-	-	1	-	1	2	1	12
Birds P-S	2	6	-	1	1	-	1	2	1	14
Fish EoM	5	5	3	6	1	-	3	-	13	36
Coastal fish P-S	NA	4	2	2	1	-	3	-	9	21
Commercial fish P-S	4	5	-	1	1	-	3	-	6	20
Migratory fish P-S	6	-	3	2	-	-	2	-	9	22
Hazardous substances EoM	-	1	3	6	1	-	2	-	5	18
Hazardous substances P-S	1	1	3	5	1	3	1	-	5	20
Litter EoM	2	3	2	1	1	1	1	-	3	14
Mammals EoM	2	3	2	-	4	-	-	1	-	12
Mammals P-S	1	4	1	-	-	-	-	1	-	7
NIS EoM	4	2	1	2	-	2	1	-	3	15
Noise EoM	3	1	2	-	1	2	-	-	3	12
Nutrients from agriculture EoM	2	1	2	1	*	1	3	-	*	10

Values are counts of contributing experts, not survey responses, i.e. multiple experts contributing to a single survey response are each counted individually. Responses returned by Observers are included in the value of the hosting Contracting Party. EoM = effectiveness of measures, P-S = pressure-state linkages, * indicates data submitted by correspondence. No German areas are included in the coastal fish P-S survey, indicated as NA in the table.

Effectiveness of measures

The information on the effectiveness of measures comes from two sources: expert surveys and existing literature and data.

Expert surveys

In the expert surveys, the effectiveness of measures in reducing pressures was, in most cases, assessed as a percent (%) change in a specific pressure from a specific activity due to the implementation of a measure type (generalized measure). Measure types were developed to be general enough to encompass multiple closely related measures across the region, yet to also be applicable to concrete measures applied in different parts of the Baltic Sea. This approach also limits the number of individual measures to be evaluated, while also being specific enough to allow for meaningful evaluation of their effectiveness by experts.

The survey included two types of questions on the effectiveness of measures types. First, experts were asked to simultaneously assess the relative effectiveness of the measure types on a scale of no effect – highest effect and the certainty of that effectiveness on a scale of uncertain – certain. Second, experts were requested to assess the percent effectiveness of the most effective measure type in reducing the specific pressure from the specific activity. Information on the percent effectiveness of the most effective measure type from the second question and on the relative effectiveness of all measure types from the first question enabled the percent effectiveness of all measure types to be assessed.

The only topic that deviates from this general approach is nutrient runoff from agriculture, where the expert survey was constructed somewhat differently. It enabled respondents to provide both model- and expert-based estimates of the effectiveness of measures. Model-based estimates were preferred, when available, but as these were not available for all Baltic Sea countries, expert assessments were welcomed.

Literature review

A literature review on the effectiveness of measures was conducted in November 2019 – April 2020 for all pressure topics receiving an effectiveness of measures assessment. The aim was to compile information from scientific articles and reports providing estimates on the effects of measures in reducing pressures that could be used in the SOM analysis to complement the expert data, either by including the estimates in the SOM model or by providing comparison points. The literature review was conducted by topic, with the information collected into structured excel files.

In the literature searches, information from the Baltic Sea was prioritized, as well as information conforming to the structure of the expert surveys (i.e. specific state components or measure types). Literature was identified mainly via Google and Google Scholar online searches, or based on suggestions from ACTION project partners, topic team members or other collaborators within the HELCOM structure. Whenever possible, the topic-specific survey structure, which served as a template for building the expert surveys, was used to identify the search terms in the internet-based searches for each topic, such as specific measure types, activities, and pressures. The internet-based searches were always started in connection to the search term 'Baltic Sea area' and, if no suitable articles were found, widened to a more general search.

For example, information on the effectiveness of the measure type "Improved pharmaceutical take-back schemes" for diclofenac was searched with the following terms: "baltic sea reduce diclofenac via take-back schemes", "baltic sea mitigating diclofenac improved pharmaceutical take-back schemes", "efficiency of measure diclofenac improved pharmaceutical take-back schemes", "efficiency of measures management of diclofenac in the environment". More information is available in Annex 5 for each topic in this folder.

Studies containing at least qualitative information on the effectiveness of a measure were examined further to compile a selection of key data and information, including information about the study itself (author, year), location of the study (country, water body), certainty of assessment (either provided in the study itself or assessed by the researcher collating the information), and other attributes, whenever available, related to (dis)advantages or costs of implementing the measure. The main aim was to collect information on the measure, including a description of its extent and effectiveness, as well as links to activities and pressures. The effectiveness of a measure was recorded preferably as % pressure reduction, but also as units of total pressure reduction or qualitative descriptions, depending on availability. The final data included those studies that provided at least qualitative information on the effectiveness of a measure. The overview of collated literature data is given in the Table 6 for the individual topics. The table summarises data entries as the number of observations, identification of usable entries for the SOM model with quantitative data available, as well as the number of scientific source studies. The literature search was divided by topics between SYKE (benthic habitats, mammals, marine protected areas and input of nutrients) and the HELCOM Secretariat (birds, fish, hazardous substances, litter, non-indigenous species, and noise).

Table 6: Overview of collated literature data on the effectiveness of measures

Topic	Number of observations (of which usable in the SOM model)	Number of studies
Benthic habitats	71 (54)	25
Birds	74 (49)	8
Fish	248 (78)	76
Hazardous substances	134 (126)	44
Litter	34 (15)	10
Mammals	22 (19)	17
Marine protected areas	8 (8)	7
Non-indigenous species	50 (44)	18
Noise	143 (6)	14
Input of nutrients	71 (43)	17

Searches were performed by the HELCOM Secretariat (birds, fish, hazardous substances, litter, non-indigenous species, noise) and the Finnish Environment Institute (benthic habitats, mammals, MPAs, input of nutrients)

Pressure-state linkages

Information on the pressure-state linkages was entirely based on expert elicitation. In the beginning of the pressure-state surveys, experts were able to choose the state components and, in some cases, the geographic area they would assess the pressure-state linkages for. The surveys first asked the experts to identify up to six top pressures affecting the state component in question and assess each pressure's significance to the state component in general terms. Next, the survey proceeded to asking about the pressure reductions required to achieve state improvements. The format of the pressure-state linkage questions depended on the existence of an agreed HELCOM threshold for GES. If an agreed GES threshold exists for the state component, the pressure-state link was assessed as the required percent pressure reduction to achieve or maintain GES. If there is no agreed GES threshold, the link was assessed as the required pressure reduction to achieve a specific percent improvement in the state component. The only exception to this was for benthic habitats, where the survey asked the required pressure reduction to achieve a "noticeable state improvement" in the benthic habitat being evaluated. Experts were requested to assess the minimum, most likely and maximum pressure reduction required, to allow them to express possible uncertainty, as well as to provide the model with a more realistic estimate of the pressure-state linkages.

Other sources of pressure reduction data for nutrients

Due to the relative abundance of data on the topic of nutrients, expert evaluations were not the major source of input data to the SOM model. Instead of calculating the pressure reductions from data on activity–pressure contributions, effectiveness of measures, and existing measures, as for the other topics in the SOM analysis, the analysis for the input of nutrients took advantage of other assessments to provide projected pressure reductions. For nutrients, direct sectoral/vectoral projections from external sources are combined with the activity–pressure contribution data (source apportionment) to create projected pressure reduction estimates. These direct sectoral/vectoral projections estimate pressure reductions based on the assumption that a specific set of measures are fully implemented. Two data sets have been generated in this way: projected reductions in nitrogen and phosphorus from municipal WWTPs and projected reductions in the atmospheric deposition of nitrogen. Description of the methodology for these assessments is included below.

Projected reductions in nitrogen and phosphorus from municipal WWTPs

HELCOM ACTION project Work Package 4 estimated potential reductions in nitrogen and phosphorus to each of the HELCOM PLC sub-areas from municipal wastewater treatment plants (MWWTPs), assuming the requirements of the HELCOM recommendation 28E/5 and the EU Urban Wastewater Directive are met. These documents place limit values on the concentration of nitrogen and phosphorus in MWWTP discharge or the required nutrient reduction percentage in MWWTP discharge, but do not stipulate the measures used to reach these targets. As a result, it is not clear what specific measures within the catalogue of existing measures would be implemented to realize these reductions.

Potential reduction calculations utilized PLC-7 data, which includes both treatment plants discharging wastewaters directly to marine wasters and also inland plants. However, as treatment reduction percentages are not part of the PLC database, potential reduction was only evaluated against nutrient concentrations in MWWTP discharge. While MWWTPs represent a significant bulk, they are not fully representative of other WWTPs and this may thus result in an over-estimation of potential reduction. Total phosphorus (PTOT) and total nitrogen (NTOT) loads of individual WWTPs were divided by flows to obtain nutrient concentrations in MWWTP discharge. These concentrations were compared to the nitrogen and phosphorus limit values of the HELCOM recommendation and EU directive. Where the HELCOM and EU limit values differed, the stricter value was used. If the calculated concentration was above the limit value, the difference in mg/l was converted to tons for the estimation of the remaining reduction potential. Additionally, retention of nutrients in inland waters was taken into account to obtain the estimate of the actual reduction potential benefitting the Baltic Sea.

Data for MWWTPs for the year 2017 (PLC-7 data) was collected from the PLC database. Russia has only submitted aggregated data and the limit values were applied to these aggregated units as if they were a single MWWTP. This likely causes an over-estimation of potential reduction, when the limit values for larger plants are applied to what may be a collection of smaller plants. Similarly, Sweden has only submitted aggregated data for inland MWWTPs to the PLC-database, but for the analysis conducted by HELCOM ACTION Work Package 4, Sweden submitted data of individual plants. Population equivalent numbers (PE) were mostly missing in the database, but some countries (Denmark, Finland, Germany, Poland and Sweden) could submit this information, enabling the classification of plants according to the PE numbers. Since there is a strong correlation between the wastewater flow and PE (r2 0.81, n = 1741), the flow was used to estimate the missing PE values according to this formula: PE = flow*0.00904+4265.

As there is no estimate of the retention of individual plants in the PLC-database, inland nutrient retention was estimated in other ways: A) For Danish plants 25% NTOT retention and 10% PTOT retention were used (Lars Svendsen, personal communication); B) To estimate the retention for other countries, MWWTP loads per sub-catchments were summed and the sums were compared with source apportionment figures (MWWTP loads reaching the Baltic Sea) derived from the PLC-7 data; and C) Many countries (LT, LV, PL, RU) were lacking MWWTP loads in their source apportionment figures and for those countries published retention estimates were applied (Stålnacke et al. 2015).

Projected reductions in atmospheric deposition of nitrogen

The HELCOM ENIRED II project has modelled the potential reduction of airborne input of nitrogen by 2030 due to implementation of the Gothenburg Protocol/EU-NEC Directive. ENIRED II provides data on total nitrogen deposition in 2005 and 2030, and from this a percent reduction can be calculated. However, in order to better align with the base year used in the SOM analysis (2016), estimated nitrogen deposition for 2014 was calculated using the nutrient source apportionment data developed for the SOM analysis (see section 7). The 2014 baseline for nutrients is somewhat out of sync from the 2016 base year of the analysis, however, of the available data on input of nutrients, the 2014 data set best matches the 2016 base year. This estimated value for 2014 was then used as the baseline in the SOM analysis and a percent reduction in the atmospheric deposition of nitrogen between 2014 and 2030 was calculated. This results in estimated reductions for each of the seven PLC sub-areas for: 1) transboundary deposition and 2) deposition originating from the HELCOM Contracting Parties, Baltic Sea shipping, and North Sea shipping.

9. Development of human activities

The data sources on the future development of human activities (Step 5) included both national and regional assessments, reports, articles and project deliverables. The information sources are listed and shortly described in Table 5 (placed at the end of this section). They cover national information from EU member states, including information based on their Initial Assessments for the EU Marine Strategy Framework Directive (EC 2008), several region-level project reports on marine activities and their future development, and scientific articles providing information on the potential development in activities. Annex A presents detailed information of the projected regional and national development for each activity.

Agriculture

The scenarios for agriculture were developed using changes in agricultural goods production as a proxy for the development of the activity. The available information indicates different future development trends for various agricultural products and countries. Based on the lack of a clear uniform trend in the mid-term projections and predicted stable development for the regional long-term projection, “no change” was considered to depict the most likely scenario. For obtaining the quantitative decrease and increase scenarios, the range in the product group specific changes from Salamon et al. (2019) for 2020-2030 were extended to cover the period 2016-2030 and rounded. Alternative scenarios that were used for the SOM analysis are presented in Table 7.

Joint scenarios for the whole sea region are provided. The available information indicates possibly different trends in the Latvia, Lithuania and Poland (increasing activity) compared to other countries (e.g. no changes for Denmark, Germany and Sweden). However, additional information collection and analysis would be needed to provide justified quantitative estimates which could be used for sub-basin scale assessments.

Table 7. Alternative scenarios on future development of agriculture in the Baltic Sea region proposed for the SOM analysis. No change depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Decrease	Decrease by 10%
Increase	Increase by 10%

Forestry

The scenarios for forestry were developed using changes in felling as a proxy for the development of the activity. Based on the available literature, felling will increase in the Baltic Sea region by 2030. Therefore, regional scenarios were developed for a small, moderate and large increase in addition to a no change scenario. Scenarios used for the SOM analysis are presented in Table 8. Small and large increase scenarios were based on the regional predictions (UN 2011, Jonsson et al. 2017), assuming that the increase is linear.

Moderate increase scenario was derived from the average of the two regional projections. The moderate increase is assumed to represent the most likely scenario. The predicted changes in felling are small, and the developed scenarios are assumed to cover possible variations and uncertainties in the future development of the activity.

The collected information does not allow quantitative assessment of possible future trends for individual countries, except for Finland. Qualitative information is available only for two three countries (Estonia, Finland and Sweden), showing either no change or an increasing trend. Additional information collection and analysis would be needed to provide justified quantitative estimates, which could be used for sea (sub) basin scale assessments.

Table 8. Alternative scenarios on future development of forestry in the Baltic Sea region proposed for the SOM analysis. Moderate increase depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 5%
Moderate increase	Increase by 7%
Large increase	Increase by 9%

Fish and shellfish harvesting

Most of the available projections indicate that commercial fishing will remain at its current level in the Baltic Sea. The most likely scenario for the development of the fishing activity is therefore no change. Since the available information does not suggest a clearly increasing or decreasing future trend for fishing activity in the whole Baltic Sea level, alternative scenarios were developed for both increasing and decreasing development, in order to cover possible variations and uncertainties in the future development. However, no quantitative estimates for the most likely future development of commercial fishing were available for suitable timescales.

The use of information on changes in fishing effort within the past 10-15 years (ICES 2019a, 2008-2017; STECF 2016, 2017, 2018a, 2019) was considered when developing the quantitative scenarios for commercial fishing, as they could provide some basis for assessing possible future development. However, past changes in fishing effort are quite large, and there are no indications that the significant decrease in fishing effort would continue, as qualitative projections indicate no major changes in fishing activity by 2030. Thus, the decrease and increase scenarios were adjusted to be more moderate. Scenarios for the SOM analysis are presented in Table 9.

Table 9. Alternative scenarios on future development of fishing in the Baltic Sea region proposed for the SOM analysis. No change depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Moderate decrease	Decrease by 10%
Moderate increase	Increase by 10%

Marine aquaculture

Based on available projections, production in marine aquaculture will increase on the regional scale. Future scenarios are therefore developed to cover small, moderate and large increases in addition to no change scenario (Table 10).

No suitable quantitative predictions for the future development of marine aquaculture were available. Quantitative scenarios were derived from the past development in Denmark, Finland and Sweden (FAO 2019a-c), which cover most of the marine aquaculture in the Baltic Sea area (HELCOM 2018a, WWF 2010). Scenarios were developed to cover possible variations and uncertainties in the future development of the activity assuming that the scale of the future development will not exceed the trend in the past 10-20 years. Scenarios that could be used for the SOM analysis are presented in Table 10. The scenarios are based on weighted averages of past changes in aquaculture in these three countries.

The past increase of 29% in marine aquaculture from 1998-2007 to 2008-2017 and the average annual increase of 3% within the past 10 years (FAO 2019 a-c) were extrapolated to 3% annual increase in 2016-2030. This value was used as the large increase scenario since in Denmark, where the marine aquaculture production is highest, no further increase is expected in the near future and the projections for Finland (Gulf of Finland and the Archipelago Sea) are not uniform. A moderate increase scenario was set to be half of the large increase scenario and small increase scenario as half of the moderate increase scenario. There is not enough information to provide a most likely scenario, and the uncertainties are considered to be high.

The activity and its development are not evenly distributed across the Baltic Sea, and the scenarios are provided to cover only combined projections for Denmark, Finland and Sweden. The collected information does not allow assessment of possible future trends for other areas of the Baltic Sea and by sub-basins.

Table 10. Alternative scenarios on future development of aquaculture in Denmark, Finland and Sweden proposed for the SOM analysis. There was not enough information to provide the most likely scenario and the uncertainties are considered to be high.

Scenarios	Change in 2016-2030
No changes	0%
Small increase	10%
Moderate increase	20%
Large increase	40%

Marine shipping

The available projections indicate an increasing trend for shipping in the Baltic Sea region. Therefore, scenarios are developed for a small, moderate and large increase in addition to a no change scenario. The scenarios are presented in Table 11. They were developed to cover the variation and uncertainties in the projected future development of different indicators for shipping, excluding one apparent outlier (WWF 2010). The small change scenario was derived from the predicted increase in marine shipping in the Baltic LINes report (2018), and the large increase scenario was derived using the projected change in the cargo volume in the reference scenario of a modelling study by Fridell et al. (2016) as a proxy for development of shipping. The moderate increase scenario was derived as a mid-range value of the small and large increase scenarios and depicts the most likely scenario.

Joint scenarios for the whole sea region are provided. The trends are rather similar also when looking per country, i.e. an increasing trend is generally expected. However, the magnitude of increase might differ in various countries and sub-basins. Based on expert opinions in HELCOM (2018c), shipping is expected to increase in all areas except the Archipelago Sea. However, additional information collection and analysis would be needed to provide justified quantitative estimates which could be used for a sub-basin scale assessments.

Table 11. Alternative scenarios on future development of shipping in the Baltic Sea region proposed for the SOM analysis. Moderate increase depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 8%
Moderate increase	Increase by 20%
Large increase	Increase by 30%

Marine transport infrastructure

Based on the available information, marine transport infrastructure is expected to increase in the Baltic Sea region. Scenarios for future development were therefore developed for a small, moderate and large increase, in addition to a no change scenario. Quantitative estimates were developed to cover possible variations and uncertainties in the future development of the activity. A moderate increase scenario was based on the predicted increase in port throughput (Baltic Port Organization 2012), and the large increase scenario was derived using the projected change in the cargo volume in the reference scenario of a modelling study by Fridell et al. (2016) as an indicator for development in marine transport infrastructure (2% per year). The small increase scenario was derived from the average of the no change and moderate increase scenarios. Moderate increase is considered to represent the most likely scenario (see Table 12).

Increasing trends are expected also for individual countries, except for Denmark. However, the magnitude of the increase is expected to differ between various countries and sub-basins. Additional information collection and analysis would be needed to provide justified quantitative estimates which could be used for a sub-basin scale assessments.

Table 12. Alternative scenarios on future development of marine transport infrastructure in the Baltic Sea region proposed for the SOM analysis. Moderate increase depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 10%
Moderate increase	Increase by 20%
Large increase	Increase by 30%

Tourism and leisure activities

The available information indicates an increasing trend for tourism and leisure activities across the whole region. Future development scenarios for the SOM analysis were therefore developed for a small, moderate and large increasing trend in addition to a no change scenario.

Joint scenarios for the whole sea region are provided in Table 13. The moderate and large increase scenarios were developed based on the range predicted for the growth of marine tourism in Europe (EC 2012), and the small increase scenario was derived as an average of the no change and moderate increase scenarios. Furthermore, these scenarios generally adhere to the projected increases for different sectors under tourism. The scenarios are assumed to cover possible variations and uncertainties in the future development of the activity. Moderate increase depicts the most likely scenario.

Available information also indicates an increasing trend for individual countries. However, the magnitude of the change may vary between countries and subregions, and additional information collection and analysis would be needed to provide justified quantitative estimates which could be used for sub-basin scale assessments.

Table 13. Alternative scenarios on future development of tourism and leisure activities in the Baltic Sea region proposed for the SOM analysis. Moderate increase depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 15%
Moderate increase	Increase by 30%
Large increase	Increase by 40%

Offshore wind energy production

The available information indicates a strongly increasing trend for offshore wind energy production at the regional level. Future development scenarios for the SOM analysis were therefore developed for a small, moderate and large increase, in addition to the no change scenario.

Predicted future changes in the activity have been reported using the metrics ‘area covered by offshore wind farms’ or as capacity (MW). The areal coverage is assumed to better reflect the activity-pressure linkage. However, since the relative trends for both indicators were similar in the Baltic LINes report, where both parameters were included (only slightly higher values for capacity; Hüffmeier & Goldberg 2019), the indicators were used together as proxies for the development in the activity. Joint scenarios for the whole sea region are provided in Table 14.

The scenarios were derived based on regional level information. The small, moderate and large increase scenarios were based on an increase in capacity and number of farms as projected in WWF 2010, increase in capacity as projected in HELCOM (2018a) and increase in areal coverage as projected in Hüffmeier & Goldberg (2019), respectively. Moderate increase depicts the most likely scenario, and the alternative scenarios are assumed to cover the most probable variation in the future development. It should be noted that there are differences in the scale of the predicted increase between individual countries (Hüffmeier & Goldberg 2019). However, increase in the activity is predicted for all countries except for Latvia, where establishment of offshore wind energy production is not expected by 2030.

Table 14. Alternative scenarios on future development of offshore wind energy production in the Baltic Sea region proposed for the SOM analysis. Moderate increase depicts the most likely scenario.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 150%
Moderate increase	Increase by 290%
Large increase	Increase by 350%

Urban sewage water systems

Scale and application of sewage water systems is predicted to grow in urban areas across the Baltic Sea region. Future development scenarios for the activity were therefore developed for a small, moderate and large increases, in addition to a no change scenario.

Quantitative predictions for the future development of the activity were not available, and the scenarios were hence based on the development of factors that affect the activity: population numbers and connection of population to urban wastewater collecting systems.

Population is expected to increase from 2016 to 2030 only in Denmark (5%), Finland (1%) and Sweden (7%), and hence increase in the sewage water systems activity is on a regional level probably more related to increase in connectivity. Urbanization in the Baltic Sea countries is expected to occur at rate of 2-5% from 2016 to 2030, which is likely to increase connectivity. Moreover, it was assumed that the UWWTD Article 3 will be implemented by 2030 by all Baltic Sea countries that are also EU members. The degree of compliance was 100% in all countries except for Poland and Estonia. In Poland, the population is expected to decrease, but urbanization and the compliance to article 3 are assumed to increase, and hence the sewage water systems activity could be assumed to increase. Similarly, in Estonia the development of the activity is affected by the decrease in population and an increase in connectivity due to urbanization and achieving compliance with article 3.

Alternative scenarios for the SOM analysis are presented in Table 15. Joint scenarios for the whole sea region are provided. Based on available projections for connectivity to urban wastewater collection systems, the increase in sewage water systems activity is predicted to be equal to or below 5% in all Baltic Sea countries except for Estonia and Poland. In Poland, a connectivity increase of up to 10% maximum could be expected. Due to an increase in population, the increase in sewage water systems could be expected to exceed 5% also in Denmark and Sweden. Therefore, 8% was selected as a large increase scenario. Moderate increase was set to 4%, which is the average of high increase and no change scenarios, and also represents an average urbanization rate within Baltic Sea countries. The small increase scenario is the average of moderate increase and no change scenarios. The scenarios are assumed to cover possible change of the activity. However, the most likely scenario cannot be indicated based on the available information.

Table 15. Alternative scenarios on future development of sewage water systems in the Baltic Sea region proposed for the SOM analysis. The most likely scenario cannot be indicated.

Scenarios	Change in 2016-2030
No change	0%
Small increase	Increase by 2%
Moderate increase	Increase by 4%
Large increase	Increase by 8%

10. Data validation and evaluation

The data from the expert surveys on activity-pressure contributions, effectiveness of measures and pressure-state linkages, as well as the literature review on the effectiveness of measures was validated by HELCOM Working Groups in September 2020. The validation took place intersessionally (via correspondence). Topic-specific summary statistics and distributions of the responses were presented for validation. The data included also summary information of the background of the respondents, i.e. their country, organization type, field and years of experience.

Some formatting of the expert survey data was required before it could be used in the SOM analysis and model. Answers to the effectiveness of measures and pressure-state surveys that are based on group responses were clarified by asking for details on the individual contributions that make up the group response, i.e. whether the experts could have answered all the questions also individually. This allowed for deciding whether to treat the group response as comparable to a single expert response, or as having a higher weight than a single expert response. Answers to the activity-pressure surveys represent national responses. Thus, each country was given the same weight (one) in the analysis, and if there are several individual experts representing a country, the weight of their answers sums to one.

Initial examination of the data has revealed some issues. In some cases, the responses for the minimum, maximum and most likely values were inconsistent, such that the most likely is higher than the maximum. In those cases, a simple error was assumed, and the values for the most likely and maximum were exchanged.

The survey software problem in the effectiveness of measures survey resulted in experts having to review and complement their original answers if responses to the relative effectiveness of a measure type and certainty of that effectiveness were missing (so-called incomplete response). Responses which were reviewed by the experts were included in the analysis normally. For responses which were not reviewed, responses to the specific relative effectiveness of measure types question (activity-pressure pair) were discarded if the effectiveness response is missing for one or more measure types. If the certainty response for the measure type is missing, the percent effectiveness of the most effective measure was used to scale all the effectiveness responses, but the response to the specific measure type was removed.

All complete responses (relative effectiveness and certainty estimates are available for all measure types in the specific grid question) were included in the analysis.

In general, missing responses to questions or parts of questions are treated as missing values.

11. Integration of the expert survey and literature data

For the effectiveness of measures (Step 4), data from expert surveys is complemented with information from existing literature, reports and models on effectiveness of measures for all topics. These literature data can be used in different ways in the SOM analysis. The usability of such data depends on whether they can be linked to the measure types (i.e. generalized measures) employed in the expert surveys. In principle, it is possible to incorporate the literature estimates in the SOM model or use them as comparison points to the expert data. Inclusion of the literature estimates in the SOM model requires in most cases that the format of the data corresponds to the format of the expert responses, i.e. enables assessing the percent reduction in a pressure from the measure type.

Direct substitution of expert responses is not, however, straightforward, because the observational or experimental results may not be produced for the Baltic Sea, the formulation of measures, effectiveness or state components may differ from the one used in the SOM analysis, or the research question has not been directed specifically to study the effectiveness of measures.

The integration of the literature data with the expert data depends on the format of the data (i.e. whether it is possible to use the data directly in the SOM model).

a) Cases when it is possible to use literature data in the SOM model

Separate SOM analyses are run using 1) only expert survey data and 2) both literature and expert survey data, by replacing the expert survey data points with the literature data, when available. Literature data cannot cover all data points in the model, so it is not possible to estimate a separate model using only literature data.

b) Cases when it is not possible to include the literature data in the SOM model

The literature estimates are used as external points of comparison and they are reflected in the discussion of the model results.

If the literature estimates cannot be linked to measure types or existing measures, new measure types could be defined. These can be useful in assessing the effectiveness of potential new measures, as is addressed in a separate task of the ACTION project.

12. Consideration of certainty and confidence

An important aspect of the SOM analysis is the transparent consideration and presentation of the certainty and accuracy of the results, and the suitability of their use in the BSAP update process or other management decisions/actions. In simple terms, the higher the uncertainty, the lower the precision in the outcome and thus the stronger the need for careful application of the results in association with other key literature and assessment outcomes.

Certainty aspects are considered in the analysis in several ways, including 1) explicit evaluation of the certainty of the input data collected via expert surveys and literature reviews, 2) confidence of the experts in their responses to the survey questions, 3) scenario analysis and 4) probabilistic modelling and presentation of the results. The purpose is to quantify the uncertainty and ensure the systematic and transparent coverage and presentation of certainty aspects.

1) Certainty of the input data or knowledge to the SOM analysis is assessed both for the expert responses and literature data. The expert surveys allowed for expressing certainty of knowledge in two ways:

a) In the effectiveness of measures surveys, experts assessed simultaneously the effectiveness of the measure type and the certainty of that effectiveness (see Step 4 in Part I). When evaluating certainty, they were requested to consider the level of scientific evidence on effectiveness, geographic variation in the effectiveness, and grouping of different measures under one measure type.
b) In the activity-pressure and pressure-state surveys, experts were able to express their answers using a range, as they were requested to estimate the minimum, maximum and most likely values (see Step 6 in Part I). For example, they were able to provide the minimum, maximum and most likely pressure reductions required to achieve good status, and thus express potential uncertainty in their estimations. Experts could also provide only the minimum and maximum values, which gives the range for the estimate without specifying the most likely value.

These certainty assessments are used to define expert-specific distributions, e.g. of the effectiveness of a measure type, or the required pressure reduction to achieve GES. The distributions include values between the minimum and maximum estimates and give higher probability to values close to the average/most likely estimate. They capture the certainty of the experts' assessment – when certainty is lower or the minimum and maximum values are further apart, the expert-specific distribution is wider and allows for a larger range of values. Expert-specific distributions are further combined across experts to form pooled distributions. The pooled distributions include this element of certainty, as well as show the differences in responses across experts. The distributions are depicted using the most likely (expected) values and their standard deviations and presented in graphs which show how the responses are distributed. Both the standard deviations and the graphical presentation of the distributions illustrate the variation in the responses. When standard deviation is high, values are spread over a wider range, and when it is low, values are closer to the most likely value. Probability distributions show the probabilities of occurrence of possible outcomes, i.e. which values are more likely than others.

For more detailed information on the use of certainty information in the SOM model, see Section 15 in Part III).

2) Confidence was measured by asking experts to evaluate their confidence in the responses they have given in the effectiveness of measures and pressure-state surveys, on a three-point scale of high, medium and low. The question was asked in relation to effectiveness of measures questions (relative effectiveness and certainty of that effectiveness and percent effectiveness questions) and pressure-state linkages (identifying significant pressures to the state component and required pressure reductions). The confidence responses are reported together with the results of the analysis to provide additional information for assessing the certainty of the findings.

In the literature review of effectiveness of measures, information on certainty and confidence was collected together with the effectiveness estimates. The certainty component included the variation (e.g. range) in the effectiveness of the measure, and the confidence was represented by the reported or assessed confidence of the effectiveness estimate in the source material. When the effectiveness of a measure is reported as a range, the range can be used to define an observation-specific distribution in a similar manner as for the expert responses to capture certainty of the estimate. When effectiveness is reported as a point estimate in the source material, it is used as it is in the SOM model. The confidence of the effectiveness estimate, given as a qualitative level (low, moderate, high), can be used similarly to the experts' evaluation of their responses and reported together with the results.

3) Scenario analysis is used to account for the uncertainty and variation in the projections on the future development of human activities (Step 5). Three or four alternative scenarios were constructed for each activity to cover the whole range of likely future changes. These include 1) no change, 2) small/negative change, 3) moderate/most likely change and 4) large/positive change scenarios. The scenarios enable drawing conclusions on how the different assumptions on the change in human activities impact the results of the analysis.

4) The SOM analysis is based on probabilistic modelling, and most of the results are presented in probabilities and probability distributions. The probability distributions describe the views of experts on activity-pressure contributions, effectiveness of measure types and pressure-state linkages, and are defined based on the three-point estimates (minimum, most likely and maximum) derived from expert judgement. The main results of the SOM analysis are presented as the probability of achieving good state or specific state improvements with the projected pressure reductions.

In addition to certainty and confidence, the number of experts contributing to each data element are reported in the results. This shows the extent of data behind the results and provides supporting information for evaluating the accuracy of the results (Table 4).

Table 4. Number of experts contributing to each survey and sub-topic. This is based on the response count by sub-topic, which takes into account group responses. Actual response counts for individual questions may be lower due to skipped questions, technical errors, and variation in group response contributions within a sub-topic. Responses to the agriculture survey are not included in this table as responses are collected by country rather than expert; see Table 3 for summary of responses. EoM = effectiveness of measures, P-S = pressure-state linkages

Survey	Sub-topic	Geographic area	Weighted response count
EoM Benthic		Whole Baltic	20
P-S Benthic	hard substrate vegetation dominated community	Kattegat	5
		Southern Baltic	9
		Eastern Baltic	5
		Northern Baltic	4
	soft substrate vegetation dominated community	Kattegat	2
		Southern Baltic	7
		Eastern Baltic	3
		Northern Baltic	3
	hard substrate epifauna dominated community	Kattegat	5
		Southern Baltic	10
		Eastern Baltic	3
		Northern Baltic	3
	soft substrate infauna dominated community	Kattegat	3
		Southern Baltic	9
		Eastern Baltic	4
		Northern Baltic	4
	coarse substrate infauna dominated community	Kattegat	2
		Southern Baltic	5

Survey	Sub-topic	Geographic area	Weighted response count
		Eastern Baltic	2
		Northern Baltic	2
EoM Birds		Whole Baltic	12
P-S Birds	Common eider - Breeding Season	Whole Baltic	9
	Great cormorant - Breeding Season	Whole Baltic	8
	Sandwich tern - Breeding Season	Whole Baltic	3
	Long-tailed duck - Wintering Season	Whole Baltic	7
	Red-throated diver - Wintering Season	Whole Baltic	6
	Great black-backed gull - Wintering Season	Whole Baltic	4
EoM Fish		Whole Baltic	36
P-S Coastal Fish	Perch and other coastal piscivores	Gulf of Bothnia	10
		Gulf of Finland	3
		Gulf of Riga	2
		Central (Swedish coastal areas only)	9
		Eastern Gotland Basin (Latvian and Lithuanian coastal areas only)	2
		South (Polish coastal areas only)	3
	Cyprinids and other mesopredators	Gulf of Bothnia	7
		Gulf of Finland	3

Survey	Sub-topic	Geographic area	Weighted response count
		Gulf of Riga	1
		Central (Swedish coastal areas only)	6
		Eastern Gotland Basin (Latvian and Lithuanian coastal areas only)	2
		South (Polish coastal areas only)	3
	Flounder	Central (Swedish coastal areas only)	6
		Eastern Gotland Basin (Latvian & Lithuanian coastal areas only)	1
		Southwest (Danish coastal areas only)	4
		South (Polish coastal areas only)	8
P-S Commercial Fish	Herring SD 20-24, spring spawners		9
	Herring SD 25-29, 32 (excl. Gulf of Riga)		14
	Herring SD 28.1 (Gulf of Riga)		1
	Herring SD 30-31		8
	Sprat SD 22-30, 32		16
	Cod, western		10
	Cod, eastern		19
	Plaice		7
P-S Migratory Fish	Salmon in assessment units 1-2		7

Survey	Sub-topic	Geographic area	Weighted response count
	Salmon in assessment unit 3		7
	Salmon in assessment unit 4		9
	Salmon in assessment unit 5		4
	Salmon in assessment unit 6		4
	Seatrout - Gulf of Bothnia		6
	Seatrout - Gulf of Finland		3
	Seatrout - Western Baltic		7
	Seatrout - Eastern Baltic		3
	Seatrout - Southern Baltic		10
	Eel - Entire Baltic Sea		11
EoM Hazardous substances	mercury	Whole Baltic	11
	TBT	Whole Baltic	10
	PFOS	Whole Baltic	12
	diclofenac	Whole Baltic	12
P-S Hazardous substances	mercury	Whole Baltic	12
	TBT	Whole Baltic	8
	PFOS	Whole Baltic	8
	diclofenac	Whole Baltic	11
EoM Litter		Whole Baltic	13
EoM Mammals	Porpoise	Whole Baltic	8
	Seals	Whole Baltic	10

Survey	Sub-topic	Geographic area	Weighted response count
P-S Mammals	Grey seal	Whole Baltic	5
	Ringed seal	Northern population	1
		Southern population	3
	Harbour seal	Kattegat	1
		Southern Baltic	2
		Kalmarsund	0
	Harbour porpoise	Western Baltic	4
		Baltic proper	2
EoM NIS		Whole Baltic	15
EoM Noise	Continuous noise 63/125 Hz	Whole Baltic	9
	Continuous noise 2 kHz	Whole Baltic	7
	Impulsive noise with peak energy below 10 kHz	Whole Baltic	9

Table 5. Data sources on projected development of human activities

Source	Type	Year	Scale	Activities	Data sources	Reference
Results of the national data call organised by HELCOM on economic and social analyses (ESA) on the EU MSFD Initial Assessments (IA)	data	2018	national	all selected activities	national assessments	HELCOM ESA data call 2018
National assessments of state of the marine environment: Economic and social analysis (national MSFD Initial Assessments)	data/ report	2019	national	all selected activities	national assessments	AKTiiVS 2018 Estonian Ministry of Environment 2019 Lithuanian internal materials for the national updated MSFD IA 2019
Consultation on initial assessment 2018, national projections of future development of activities	data/ report	2017, 2019, 2020	national	all selected activities	national assessments	SwAM 2017 German Environment Agency 2019 Ministry of Environment and Food of Denmark 2020
Development of emissions and sinks in the agricultural and LULUCF sectors until 2050	report	2019	national	agriculture forestry	model	Aakkula et al. 2019
AGMEMOD Outlook for Agricultural and Food Markets in EU Member States 2018-2030	working paper	2018	regional	agriculture	model	Salamon et al. 2018
Blue Growth Scenarios and drivers for Sustainable Growth from the Oceans, Seas and Coasts	report	2012	regional	shipping tourism and leisure offshore wind energy production	literature, GIS data, expert evaluation	EC 2012
Maritime activities in the Baltic Sea	report	2018	regional	shipping	literature, expert evaluation	HELCOM 2018c
State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016	report	2018	regional	offshore wind energy production	HELCOM Maps and data services	HELCOM 2018a
Report on regionalized SSPs and RCPs resulting in a coherent set of climate and socioeconomic scenarios for the Baltic Sea region	report	2016	regional	agriculture wastewaters	scenarios	Zandersen et al. 2016
Future Scenarios. BONUS Research Project Sustainable Shipping and Environment of the Baltic Sea Region (SHEBA) Deliverable 1.4	deliverable	2016	regional	shipping tourism and leisure	literature, forecast, stakeholder evaluation	Fridell et al. 2016

Source	Type	Year	Scale	Activities	Data sources	Reference
Shipping in the Baltic Sea – Past, present and future developments relevant for Maritime Spatial Planning	report	2016	regional	shipping	literature	Baltic LINes 2016
QUO VADIS Exploring the future of shipping in the Baltic Sea	report	2018	regional	shipping transport infrastructure	scenario	Baltic LINes 2018
2030 and 2050 Baltic Sea Energy Scenarios	report	2019	regional	offshore wind energy production	scenarios, literature, expert evaluation	Hüffmeier, J. & Goldberg, M. 2019
Blue growth – drivers and alternative scenarios for the Gulf of Finland and the Archipelago Sea, Qualitative analysis based on expert opinions	report	2018	regional	shipping transport infrastructure tourism and leisure offshore wind energy production marine aquaculture	literature, expert evaluation	Pöntynen & Erkkilä-Välimäki 2018
The European Forest Sector Outlook study II 2010-2030	report	2011	regional	forestry	scenarios, models	UN 2011
Baltic Ecoregion Programme 2010: Future Trends in the Baltic Sea	report	2010	regional	agriculture fishing aquaculture shipping transport infrastructure tourism and leisure offshore wind energy production	literature, expert evaluations	WWF 2010
Outlook of the European forest-based sector: forest growth, harvest demand, wood-product markets, and forest carbon dynamics implications 2017	article	2017	regional	forestry	model	Jonsson et al. 2017
Evaluating adaptation and the production development of Finnish agriculture in climate and global change	article	2015	national	agriculture	model	Lehtonen 2015
Effects of reducing EU agricultural support payments on production and farm income in Finland	article	2018	national	agriculture	model	Lehtonen & Niemi 2018

Source	Type	Year	Scale	Activities	Data sources	Reference
Shared socio-economic pathways extended for the Baltic Sea: exploring long-term environmental problems	article	2019	regional	agriculture fishing marine aquaculture wastewaters	scenario	Zandersen et al. 2019

PART III - MODELLING THE SUFFICIENCY OF MEASURES

13. General aim of the model

The SOM model predicts the pressure reductions (%) from existing measures (effectiveness of measures, Step 4) and the subsequent changes in environmental status (%) (pressure-state linkages, Step 6), taking into consideration the activity-pressure contributions (Step 3). Effectiveness of measures input data come from expert surveys, and whenever possible, is replaced with or compared to estimates from existing literature. The data on pressure-state linkages come from expert surveys. Activity-pressure contributions are either data- or expert-based, depending on the topic. For details on the input data and data collection, see Part II.

The results enable the probability of reaching GES to be assessed, given a reduction in total pressures affecting the state component for those components which have an existing GES threshold value. When a GES threshold does not exist, it is possible to assess the probability of achieving specific state improvements given the reduction in total pressures affecting the state component, or the pressure reductions from existing measures. The intermediate results on activity-pressure contributions and effectiveness of measure types, in conjunction with the results on pressure reductions and improvements in state also enable the scoping of feasible measure types to achieve specific pressure reductions and state improvements.

Geographical areas in the SOM model

The SOM model utilizes the 17 HELCOM sub-basins of the Baltic Sea. However, geographical divisions differ between topics and steps of the model depending on input data: the effectiveness of measures data collected from experts and literature is for the entire Baltic Sea area, the activity-pressure contributions data uses 1-17 areas depending on the topic, and the pressure-state data uses 1-6 areas depending on the topic. Further, the sub-basins included in any particular area will vary between topics and not all 17 areas will necessarily be covered by each topic. The collected data are then used to define the distributions for activity- pressure contributions, measure type effectiveness and pressure-state linkages.

Identification and implementation status of existing measures

The model uses measure types as the unit for assessing the BAU state. However, actual implementation always occurs at the level of individual measures, and therefore the model links each measure type to the existing measures (Step 1). Existing measure-measure type links are only established for existing measures which have not yet been implemented or have only been partially implemented, and measures that have been implemented but can still have new effects on pressures. These measures have the potential to still reduce pressures and improve the environmental state over the timeframe of the analysis (2016–2030). Measures that have already been fully implemented and exerted their full effect on pressures are not included in the SOM model. Existing measures that are linked to measure types also include information on the area of implementation. The area of implementation can range from Baltic-wide to sub-national. For measures affecting less than entire sub-basins, e.g. MPAs and their regulations, coastal or EEZ specific measures, the area of implementation is recorded as a proportion of the affected sub-basin. The effectiveness of existing measures is calculated by drawing values from the Baltic-wide measure type effectiveness distributions, so that the effectiveness of a measure can vary between different sub-basins and countries. However, the activity-pressure contributions are always the same in the sub-basins included in the spatial units used for assessing the activity-pressure contributions, which are often some combinations of the sub-basins.

Many existing measures are cross-listed under several measure frameworks, making it difficult to determine what is a distinct existing measure and increasing the risk of overcounting existing measures. In order to mitigate this risk, credit for implementing a measure of a certain measure type is only applied once per area. This means that if more than one existing measure of a particular measure type are being implemented in any given area, the model will only consider the effect from one implementation of the corresponding measure type. However, in cases where the measures affect less than the full sub-basin and there are multiple measures of the same type implemented in the area, the measure with the largest impact, i.e. spatial extent, is used. Since the effectiveness values for each measure are drawn individually from the measure effectiveness distributions, only the measure with the maximum of the drawn values is taken into account. This enables the extensive implementation of a measure type through different policy frameworks to have a positive impact on the effectiveness.

This mitigates the risk of overestimating the effects of existing measures.

14. Joint impacts of measure types

In principle, the effects of measures are additive (effects are added up) in the SOM model. Many measure types have joint impacts which need to be taken into account to avoid over- or underestimation of measure effectiveness. Two types of joint impacts are considered in the model:

- **Thematic overlap** in measure types due to their existence on different policy levels (global, EU, HELCOM, national) or overlapping content (e.g. MPAs in general vs. fishing closures in a specific area).
- **Chain effects of measures in reducing pressures.** Assuming that measures take effect in a chain, a measure can only impact the pressure share that remains after the preceding measures. As the pressure reductions are in percent (%), the chain effect needs to be taken into account. It is also important to note that the order of the measures in the chain has no effect on the total impact. Chain effect approach has been previously applied on a case study to assess the sufficiency and cost-effectiveness of measures to reduce beach litter items from different activities (Saikkonen, 2018).

The thematic overlap is taken into account by recognizing thematically similar measure types and considering their overlaps one by one. As a result, the overlapping measure types are set in a hierarchical order where one measure type makes another one partly or completely obsolete. The effectiveness of the measure types is reduced according to the overlaps along this hierarchical order.

Identified **thematic overlaps** fall into one of four categories. The first category consists of national management plan measure types and the constituent measure types that may be present inside such management plans. If any of the identified constituent measure types are implemented, the effectiveness of the national management plan measure type is multiplied by 0.2 (i.e. the effectiveness of the national plan is assumed to be 20% of its original effectiveness). This avoids double counting of management measures while still giving credit to the coordination value of the management plan. The second category is international management plans and the constituent measure types that may be present inside such management plans. This category is identical to the first, except that the management plan measure type is multiplied by 0.4, giving less of a discount to reflect the added value of international cooperation. The third category is measure types that are completely overlapping with other measure types. These measure types typically represent a status quo situation (e.g. current wording of Stockholm convention annexes) and a more stringent wording of the same measure type (e.g. updated wording of Stockholm convention annexes). If the more stringent measure type is implemented, then the weaker measure type is multiplied by 0 (i.e. it has no effectiveness). The final category is technical overlaps, where overlap strength is assessed on a case by case basis in 20% intervals (multipliers of 0, 0.2, 0.4, 0.6, 0.8, 1). The thematic overlaps are integrated in the chain effect. The thematic overlaps are identified spatially, meaning that there is an overlap if the measures of overlapping and overlapped measure types are implemented in the same location (country's share of a basin).

The **chain effects** are recognized by first defining individual effects (from the measure type effectiveness distributions based on survey responses and overlaps) of N actual measures affecting a pressure from an activity implemented by a country in a given basin, defined as vector $X = [x_{i=1}, \dots, x_N]$. Assuming that measures take effect in a chain, a measure can only impact the pressure share that remains after the preceding measures. For chain effects, the joint impact of a measure ***i*** can be defined by recursive function

$$\boldsymbol{f}(x_i) = \begin{cases} x_i, i = 1 \\ (1 - \sum_{j=1}^{j=i-1} \boldsymbol{f}(x_j))x_i, i > 1 \end{cases}$$

The total joint impact (=sum of joint impacts of measures) of the measures until the i:th measure can also be defined as recursive function

$$\boldsymbol{F}(x_i) = \begin{cases} x_i, i = 1 \\ \left(1 - \boldsymbol{F}(x_{i-1})\right)x_i + \boldsymbol{F}(x_{i-1}), i > 1 \end{cases}$$

The total joint impact of all N measures is $\boldsymbol{F}(x_N)$. The total joint impact of all measures is not affected by the order of measures in the vector X, and thus the total joint impact defined for chain impacts can be used to approximate the total joint impact of effects regardless of the order of the effects. If the measure effects are between 0 and 1, the total joint impact can only have values between 0 and 1. This implies that pressures cannot be reduced more than 100%.

These two types of join impacts of measures are included in the SOM analysis.

15. Model structure

Model code is available at https://github.com/LiisaSaikkonen/ACTION_SOM.

Pooling of expert judgements

The probability distributions describing the views of experts on activity-pressure contributions, measure effectiveness and on the probability of achieving good state are defined based on the three-point estimates (minimum, most likely and maximum) given directly by experts (activity-pressure, probability of reaching good state), or three-point estimates derived from expert judgements (measure effectiveness). This allows the comparison of results across different topics and consistent assessment of pressure reductions for different state components that are affected by multiple activities and pressures.

The distributions are defined from the three-point estimates of individual experts to the shape of PERT distributions. The PERT distribution is a modification of the beta distribution, where a variable can take values between any minimum and maximum values, whereas for a standard beta distribution, minimum and maximum values are fixed to 0 and 1. In the PERT distribution, the expected value is defined as $\mu = \frac{min + \gamma\ ml + max}{\gamma + 2}$ where γ=4, and min, ml and max are the minimum, most likely and maximum value respectively. In the modified PERT distribution, the weight γ can be scaled to control the probability that is assigned to tail values of the distribution, so that a higher weight puts more emphasis on the most likely value and less to the extreme values. The default weight for estimates in the SOM analysis is 4, which is the standard used in unmodified PERT distributions. In symmetrical cases, where the minimum and maximum values are of equal distance from the most likely value, the shape of the PERT distribution is similar to the shape of a normal distribution, and for unsymmetrical cases the shape is often close to a log-normal distribution.

Alternatively, triangular or uniform distribution could be used to present a case where extreme values are more probable. Also, the weight of the PERT distribution could be increased to lower the probability of more extreme values. Sensitivity analyses can later be made deviating from the base case assumptions, by using alternative distribution types that are more representative for different topics than those based on three-point estimates and that can differ among topics, if such distributions based on empirical data are available. The same principal approach applies for the other distributions used in this analysis.

Finally, the above expert-specific distributions only represent the views of individual experts. The aggregated probability distributions that define the view of all experts are defined as follows. A linear pooling method is applied where equal weight is set for each individual expert or national response (see weighting description below). An equal and large number of values is drawn from each expert-specific distribution representing, for example, a certain activity-pressure contribution. Then, these drawn values (from now on drawn values are referred to as picks), are pooled together in a multiset of picks. A discrete probability distribution is applied for each multiset, where a probability is calculated for the value intervals within this multiset. For example, if the multiset has altogether 5000 picks, of which 200 fall within the value range of 1-2%, then the probability of the value range 1-2% is 4%. These discrete distributions define the combined view of all experts, and they take into account the uncertainties expressed by each individual expert. From each of these pooled discrete distributions, a large and equal number of picks (e.g. 1000) are drawn to form ordered multiset of values, that is used in the simulations to estimate the reductions in pressure and consequential changes in state variables. It should be noted that an unequal number of experts contribute to different aggregated distributions and this affects the shape of pooled distributions and the picks drawn from them.

Responses to the majority of effectiveness of measures surveys and all pressure-state surveys are weighted on an expert level, with each contributing expert receiving an equal weight. Survey responses submitted by more than one expert (group responses) were followed up to determine individual contributions. This allowed for deciding whether to treat the group response as comparable to a single expert response, or as having a higher weight than a single expert response. The nutrient reductions from the agriculture survey represent the only effectiveness of measure survey weighted differently. It is weighted on a national basis, with each country's response receiving equal weight. However, as all surveys are expected to only provide information on a single country, this is likely to have no effect on model inputs. Finally, responses to activity-pressure surveys are weighted on a national basis, with each country's response receiving equal weight.

Activity-pressure contributions

Activity-pressure contributions (step 3) are based on responses to expert surveys (main activities contributing to a pressure) or existing empirical data (for details, see PART II). In the expert surveys, three-point estimates (min-%, max-%, most likely-%) are provided by each expert for each basin or geographical assessment unit consisting of multiple basins. In the existing empirical data not all activity-pressure contributions are assessed using surveys (e.g. benthic habitats, non-indigenous species, input of nutrients), but are instead based on other data sources. The data of these sources do not always allow for three-point estimates and instead may be represented by single values or ranges.

Aggregated discrete probability distribution for an activity ($\boldsymbol{j}$) - pressure ($\boldsymbol{i}$) contribution $\boldsymbol{C}$ for a basin ($\boldsymbol{k}$) is defined as

$$\boldsymbol{fc}_{\boldsymbol{i,j,k}}(\boldsymbol{C})$$

If the activity-pressure contribution is defined for an assessment unit of multiple sub-basins, then the same ordered multiset of picks is used for each sub-basin within an assessment unit, i.e. the values are not redrawn for each sub-basin. Thus, the same set of drawn values is used for each sub-basin within one spatial unit for activity-pressure contributions.

Effectiveness of measure types

The data on the effectiveness of measures (Step 4) come from expert surveys and from a literature review. In the expert surveys, the effectiveness is not assessed individually for actual measures, but for more aggregated measure types which are defined based on existing measures. This is done for several reasons: i) there are too many measures to assess them individually, ii) the available information on existing measures is incomplete and asymmetric, which could jeopardize equal assessment of measure effectiveness among topics, different countries and policy schemes, and iii) the measure type effectiveness can be applied to assess the effectiveness of new measures.

The effectiveness of measures survey consists of two parts. The first part is a grid question where different measure types are located based on their (relative) effectiveness (x-axis: no effect-highest effect) and certainty of their effectiveness (y-axis: uncertain-certain) to reduce a given pressure from a specific activity. Uncertainty here means the objective uncertainty arising from the level of scientific evidence on measure type effectiveness and also on the variation of measures that belong to one measure type. Such a grid question was asked for each significant activity contributing to a certain pressure, based on the activity-pressure contributions (for an example of a grid question on the effectiveness of measure types targeting one activity-pressure combination see Figure 4 in Part I). Here, the set of measure types related to each pressure $\boldsymbol{N_i}$ includes all possible measure types affecting that pressure, but some of these might not be relevant for all activities. Thus, the measure types included in the question may be subsets of $\boldsymbol{N_i}$. It is assumed that the measure type effectiveness to reduce a given pressure from a certain activity is the same for the whole Baltic Sea. However, activity-pressure contributions can vary spatially across the spatial units used for activity-pressure assessment, which means that the effects of certain measure type on the pressure reduction likely differ between different areas of the Baltic Sea. In addition, the projected pressure reductions are affected by the joint impacts of measures and the fact that the existing measures included in the SOM model vary between countries.

The relative effects of different measure types with respect to the most effective measure type (the one the most right on the x-axis) are used to scale the measure type effects. They are defined for each measure type of each grid-question by

$$E_{i,j,n} = \frac{\boldsymbol{x_{i,j,n}}}{\boldsymbol{x_{i,j,max}}}$$

where $\boldsymbol{x_{i,j,n}}$ is the position on the x-axis and max refers to the most effective measure type (most right on the x-axis).

The uncertainty values (position on the y-axis) are used to influence the range of the effectiveness of the measure type (x-axis) in reducing the pressure from an activity. Minimum certainty (uncertain) is assumed to mean that all possible effectiveness levels from no effect to highest effect are possible and the most likely effectiveness is the place on the x-axis where an expert has placed the relative effectiveness value with respect to the other measures. Maximum certainty (certain) is assumed to mean that the effectiveness of measure type always equals the most likely value, and thus there is no range but only a point value of effectiveness. The effectiveness range is symmetrically distributed around the most likely value for all measure types, but if half of the uncertainty (position from top of the y-axis) is higher than the distance of the measure type effectiveness (position on the x-axis) from either end of the x-axis, then the rest of the effectiveness range is allocated to the other end of the x-axis (effectiveness) where there is still room. Assume for example that an expert has estimated that the most likely value of a measure type effectiveness is no effect, and that the certainty related to this effectiveness is minimum (uncertain). In this case the range of effectiveness is from no effect to highest effect with a most likely value of no effect. The relative minimum and maximum effects that different measure types can take with respect to the most effective measure type can be calculated in the same way as in formula (1): $E_{i,j,n,L} = \frac{\boldsymbol{x_{i,j,n,L}}}{\boldsymbol{x_{i,j,max}}}$ and $E_{i,j,n,H} = \frac{\boldsymbol{x_{i,j,n,H}}}{\boldsymbol{x_{i,j,max}}}$, where $\boldsymbol{x_{i,j,n,L}}$ and $\boldsymbol{x_{i,j,n,H}}$ are the lowest and highest end of the effectiveness value range for the measure type respectively. Following the comments and discussion of the third meeting of the SOM Platform (SOM 3-2020) on the asymmetry of the PERT-distributions, the weight is adjusted so that the difference between the mean and most likely value is less than 5%, while at the same time constraining the maximum weight to 10.

The second part of the expert survey related to measure effectiveness (see Figure 5 in Part I) asks, in percentages, how much the most effective measure type (most right on the x-axis) reduces the pressure from the activity. The most likely effect of the most effective measure type can be defined as the mean of the given effect range or as a distribution of the values in that range. Using the mean, we can denote this effect by $\bar{R}_{i,j,max}$. The most likely effect of other measure types can be estimated as a product of the expected effect of the most effective measure type and the relative effect of a measure type with respect to the most effective measure type $\bar{R}_{i,j,n} = E_{i,j,n} \times \bar{R}_{i,j,max}$. The minimum and maximum effects for different measure types are calculated in a similar fashion but using $E_{i,j,n,L}$ and $E_{i,j,n,H}$ respectively. These effect ranges (most likely, minimum and maximum effects) define three-point estimates for each survey response. Again, the probability distributions for measure type effects as percent reduction in pressures from activities are aggregated from the PERT distributions defined for three-point estimates of individual experts. The probability distribution of a %-pressure reduction effect $\boldsymbol{R}$ of a measure type $\boldsymbol{n}$ on a pressure i from an activity j is $\boldsymbol{r_{i,j,n}}(\boldsymbol{R})$.

Calculating the projected pressure reductions

The projected pressure reduction (i.e. total pressure reduction) effect $\boldsymbol{T_{k,i}}$ of measures on a pressure $\boldsymbol{i}$ in a basin $\boldsymbol{k}$ is calculated as a sum of all effects of measures affecting pressure $\boldsymbol{i}$ in basin $\boldsymbol{k}$ multiplied by their respective activity-pressure contributions

$$\boldsymbol{T_{k,i}} = \sum_{j\in \boldsymbol{A_{k,i}}} \boldsymbol{C_{i,j,k}} \Big(\sum_{\boldsymbol{n\in N_i}} \sum_{\boldsymbol{m=1}}^{\boldsymbol{M_{k,j,i,n}}} \boldsymbol{R_{i,j,n}}\big(\mathbf{1} + \Delta_{\boldsymbol{j}}\big) - \Delta_j\Big)$$

where $\boldsymbol{C_{i,j,k}}$ is the contribution of an activity j on pressure i in basin k, $\boldsymbol{A_{k,i}}$ is the set of significant activities causing pressure i in basin k, $\boldsymbol{N_i}$ is the set of all measure types linked to pressure i, and $M_{k,j,i,n}$ denotes the number of measures of measure type n affecting pressure i from activity j in basin k, and $\boldsymbol{R_{i,j,n}}$ is the pressure reduction effect of the given measure type n on pressure i from activity j. Measure effects of individual measures are thus defined by the effectiveness of the measure type that they belong to. Baltic-wide percentage increase in an activity j based on the development scenario is defined by Δ_j.

The set of total pressure reductions $\boldsymbol{T_{k,i}}$ that is used to define the distribution of the projected pressure reduction (in %) for pressure i in basin k is calculated by using large number (N=1000) of values $\boldsymbol{C_{i,j,k}}$ and $\boldsymbol{R_{i,j,n}}$ drawn from discrete probability distributions $\boldsymbol{fc_{i,j,k}(C)}$ and $\boldsymbol{r_{i,j,n}(R)}$ [3]as described in section above on Pooling of expert judgements. The measure effect values $\boldsymbol{R_{i,j,n}}$ are corrected to include the joint effects defined in Section 14 on Joint impacts of measure types.

Measure effects for basins are drawn individually for each country and then multiplied by that country's share of the total basin area. Also, if a measure affects only certain part of some basin (for example national measures or other measures affecting only certain parts of basins), the effect is multiplied by the area of that part of the basin divided by the area of the whole basin. A probability distribution is defined for each pressure reduction in % based on the N=1000 calculated pressure reduction effects. These distributions take into account the uncertainty in the activity-pressure contributions, as well as in the effectiveness of the measure types. Further, these distributions allow for calculating the expected projected pressure reductions, constructing percentile intervals for pressure reductions, and calculating the probability to reach a specific pressure reduction.

For measures affecting pressures directly, if there are also measures that affect same pressures through activities, the pressure reductions from activities including joint impacts and effects of human development scenarios are calculated first. Direct measure impacts affect the remaining pressure.

Pressure-state linkages

The data for the pressure-state linkages (step 6) come from expert surveys. The first survey question on the pressure-state linkage asks the experts to identify the most significant pressures to the state variable (such as the abundance of some species) (see Figure 6 in Part I). These are asked separately for each assessed area/population. The pressures are weighted based on their proportion of the total significance of pressures:

$$W_{i,K,s} = \frac{\boldsymbol{y_{i,K,s}}}{\sum y_{K,s}}$$

where $\boldsymbol{y_{i,K,s}}$ is the sum of significance scores over the experts (0-5, 0 being "not very significant" and 5 being "extremely significant" in Figure 6) of the given pressure $\boldsymbol{i}$ in spatial assessment unit

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[3] The values of $\boldsymbol{R_{i,j,n}}$ can also be drawn independently for each measure belonging to a certain measure type.

$\boldsymbol{K}$ consisting of one or multiple basins for state variable $\boldsymbol{s}$ and $\sum y_{k,s}$ is the total of all summed significance scores of all significant pressures for state $\boldsymbol{s}$ in assessment area $\boldsymbol{K}$.

The second survey question about pressure-state linkages (Figure 7 in Part I) asks how much all the pressures chosen in the first question need to be reduced in order to reach or maintain good state for the state variable. If the good state and/or current state can be quantified, these values are used when phrasing the questions for pressure-state linkage. When there is no agreed GES threshold value, this question asks about pressure reductions required in order to achieve specific (%) improvements in the state variable or a noticeable improvement in the state variable.

These questions about required pressure reduction are again asked as a value range (most likely, minimum, maximum), where three-point estimates are provided by each expert. From these values, a cumulative distribution function can be defined that represents the probability of reaching a good state for different % reductions in pressures, the probability of a specific improvement in state, or a probability to reach noticeable improvement in state. Again, a pooling method is used to define aggregate cumulative distribution from expert-specific distributions. These cumulative distributions are denoted by $\boldsymbol{FS_{k,s}(TPR)}$, where $\boldsymbol{TPR}$ is the reduction in total pressure. In principal, the reduction in pressure means that all significant pressures are reduced by the same % amount. However, in reality it is very unlikely that all pressures are reduced by the same proportion, and thus the reduction in pressure $\widetilde{\boldsymbol{TPR}}_{\boldsymbol{k,s}}$ can be approximated using the pressure weights $W_{i,K,s}$ based on the significance scores from Figure 6.

Reduction in total pressure ($\boldsymbol{TPR}$) for the spatial assessment unit $\boldsymbol{K}$ and state component $\boldsymbol{s}$ is:

$$\widetilde{\boldsymbol{TPR}}_{\boldsymbol{K,s}} = \sum_{\boldsymbol{i \in I_s}} W_{i,K,s} \sum_{\boldsymbol{k \in K}} \boldsymbol{T_{k,i}} z_{k,K}$$

where $\boldsymbol{i} \in \boldsymbol{I_s}$ is the set of significant pressures for state $\boldsymbol{s}$ (resulting from the implementation of measures). The pressure reduction is calculated as a pressure significance weighted (by $W_{i,K,s}$) sum of the sums of per basin projected pressure reductions weighted by the proportion of basin area of the whole assessment unit area $z_{k,K}$.

Finally, by plugging the approximated reduction in total pressure into the function of reaching a good state for different % reductions, one is able to estimate the probability of reaching a good state for state variable $\boldsymbol{s}$. If an expected value of the total pressure reduction is applied to study how reductions in pressures increase the probability to reach good state, then the cumulative distribution function $\boldsymbol{FS_{k,s}}$ can be used to define the expected probability to reach good environmental state. Whereas, if the total pressure reduction is defined as a distribution, then the probability distribution of reaching good state with a specific probability can be assessed, and from that it is possible to estimate what is the likelihood that the probability of reaching a good state is at least some specific percent. For measures affecting state directly, the probability to reach good state is augmented by the percentage state improvement resulting from the measure.

Comparison of BAU and GES and sufficiency of measures

The previous sections have outlined how to determine the expected pressure reduction distributions with existing measures, allowing for calculation of expected pressure reductions, confidence intervals and the probability to achieve a specific percent (%) reduction in pressures. If we know a pressure target or the threshold associated with good state and the current pressure level, we can estimate the total pressure reduction required to reach a good state. Thus, for pressures that have a GES threshold/target, we can assess whether the expected pressure reduction is sufficient to reach GES for that pressure (i.e. if the expected pressure reduction from the existing measures is as large as the required pressure reduction), or estimate the probability of reaching the pressure target with the existing measures (=probability that given pressure reduction target is achieved from the distribution of the total pressure reduction with existing measures).

The cumulative distribution function of the total pressure reduction required to meet the good state $\boldsymbol{FS_{k,s}}$ is used to represent the probability of reaching a good state for different % reductions in total pressure affecting a state variable. If an expected value of total pressure reduction is applied to study how reductions in pressures increase the probability to reach good state, then cumulative distribution function $\boldsymbol{FS_{k,s}}$ can be used to define the expected probability to reach good environmental state. If the total pressure reduction is defined as a distribution, then the likelihood that the probability of reaching a good state is at least X% can be estimated.

When interpreting the results, one has to take into account the assumptions and generalizations that were made when defining and using the input distributions of activity-pressure contributions, measure type effects and probability to reach good state, and the fact that these are based mainly on expert elicitations rather than empirical data.

Adjustments for the pressure *Input of the relevant top litter items present on the beach*

Modifications to the general approach were required in order to analyse input of litter using a by-item-approach, as requested at SOM 2-2019. Firstly, respondents were asked to assess the contribution of the activities *transport – shipping*, *tourism and leisure activities (boating, beach use, water sports, etc.)*, *fish and shellfish harvesting (all gears, professional, recreations)*, and *riverine inputs* to the input of the top 10 items contributing to beach litter for each of the three HELCOM beach types (urban, peri-urban, rural; HELCOM 2018f). Assessments were done on a five point scale, where 0 indicated insignificant contribution (<5% of the total load), 1 low contribution (5-20% of the total load), 2 moderate contribution (20-40% of the total load), 3 high contribution (40-60% of the total load), and 4 very high contribution (>60% of the total load). The minimum, maximum and mean values of these contribution ranges were averaged across the three beach types and then used to calculate the activity-pressure contributions presented in this report and used in the SOM model.

Secondly, in the evaluation of effectiveness of measures, each measure type is linked to the litter items controlled by that measure type. Measure effectiveness is then assessed as the average effectiveness across all the listed litter types. One complication to this approach is the presence of the litter item category "Plastic and polystyrene pieces" which includes otherwise unidentified pieces which may or may not belong to another top litter category if properly identified. To overcome this, two further adjustments are made. Firstly, experts were asked to assess the effectiveness separately for measure types that impact the input of all top litter items and those that impact a subset of those items. Secondly, when assessing effectiveness for those measure types that impact a subset of top litter items, “Plastic and polystyrene pieces” was not included because it was considered too difficult to assess directly. Instead, effectiveness of measure types for “Plastic and polystyrene pieces” is calculated by determining the proportion of all plastic litter items recovered during beach surveys that are impacted by the measure type and applying the measure type effectiveness only to that portion. This calculation assumes that all plastic litter proportionally contributes to the litter category “Plastic and polystyrene pieces”.

Adjustments for the pressure *Input of nutrients*

A substantial amount of information for the input of nutrients comes from ACTION work package 4, which provides an overview of the division of activities and pressures related to eutrophication (i.e. nutrient inputs), creating an overview of source apportionment and identifying activity-pressure contributions (Step 3). This aspect is developed based on the national data reported to the HELCOM Pollution Load Compilation (PLC).

For the effectiveness of measures (Step 4), information on load reductions due to full implementation of existing measures is required. The information on the effectiveness of measures is provided per activity: waste water treatment (reductions achieved by implementing the HELCOM Recommendation 28E/5 on municipal waste water treatment), atmospheric nitrogen emissions (based on EMEP data and predictions), agriculture (expert survey on the nutrient runoff from agriculture guided by HELCOM Agri group), and scattered dwellings (joint survey with the PLC-7 project). Inclusion of the estimated reduction from scattered dwellings is uncertain due to the development timeline for PLC-7.

Thus, only nutrient runoff from agriculture is based on expert elicitation. The expert survey follows the general format of the effectiveness of measures survey for the other topics in the SOM analysis, but there were also significant adjustments.

The survey asked separately for effectiveness of measures for the input of phosphorus and nitrogen. First, the survey allowed the respondents to provide assessments of the effects of measures either based on model estimates, expert evaluation, or both. The model-based estimates could be provided as the total reduction in nutrient runoff or by measure (based on HELCOM palette of measures), in tons or percent. The expert-based estimates could be provided as a total reduction in nutrient runoff (tons or percent) or the relative effectiveness of measures, as for other topics in the SOM analysis. Secondly, nationally consolidated responses were preferred.

Technical implementation of the model

Model was implemented using Python programming language and Spyder IDE. Python was chosen over for example R or MATLAB due to various reasons. Python is developed under an open source license and therefore is freely usable and distributable. In general Python is considered faster than MATLAB or R. With respect to syntax and semantics it draws inspiration form classic programming languages and thus emphasizes code readability. Python is compatible with multiple optimization software and libraries including its own optimization functions of SciPy library. Such functionality could be used for cost-effectiveness analysis or for other decision optimization analyses. Whereas R has a stronger focus on statistics, Python has a more general scope, and thus allows more options for the future development and deployment of the model.

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SOM report series

HELCOM ACTION 2021a. Sufficiency of existing measures to achieve good status in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MainSOMReport

HELCOM ACTION 2021b. Methodology for the sufficiency of measures analysis. Available at: http://www.helcom.fi/SOM/MethodologyReport

HELCOM ACTION 2021c. A practical guide to interpreting the SOM results. Available at: http://www.helcom.fi/SOM/PracticalGuide

HELCOM ACTION 2021d. Sufficiency of existing measures for benthic habitats in the Baltic Sea. Available at: http://www.helcom.fi/SOM/BenthicHabitatsReport

HELCOM ACTION 2021e. Sufficiency of existing measures for coastal fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CoastalFishReport

HELCOM ACTION 2021f. Sufficiency of existing measures for commercial fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CommercialFishReport

HELCOM ACTION 2021g. Sufficiency of existing measures for hazardous substances in the Baltic Sea. Available at: http://www.helcom.fi/SOM/HazardousSubstancesReport

HELCOM ACTION 2021h. Sufficiency of existing measures for input of nutrients in the Baltic Sea. Available at: http://www.helcom.fi/SOM/NutrientsReport

HELCOM ACTION 2021i. Sufficiency of existing measures for marine litter in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MarineLitterReport

HELCOM ACTION 2021j. Sufficiency of existing measures for marine mammals in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MarineMammalsReport

HELCOM ACTION 2021k. Sufficiency of existing measures for migratory fish in the Baltic Sea. Available at: http://www.helcom.fi/SOM/MigratoryFishReport

HELCOM ACTION 2021l. Sufficiency of existing measures for non-indigenous species in the Baltic Sea. Available at: http://www.helcom.fi/SOM/NISReport

HELCOM ACTION 2021m. Sufficiency of existing measures for underwater noise in the Baltic Sea. Available at: http://www.helcom.fi/SOM/UnderwaterNoiseReport

HELCOM ACTION 2021n. Sufficiency of existing measures for waterbirds in the Baltic Sea. Available at: http://www.helcom.fi/SOM/WaterbirdsReport

HELCOM ACTION 2021o. Sufficiency and cost-effectiveness of potential new measures to achieve good status in the Baltic Sea. Available at: http://www.helcom.fi/SOM/CostEffectivenessReport

Model code is available at: https://github.com/LiisaSaikkonen/ACTION_SOM

Annex A. Information on the projections on the development of human activities

Agriculture

Regional development

There is no uniform view on the future development of agriculture in the Baltic Sea area, since the projected trends differ between agricultural products and countries. Long-term development of agriculture in the Baltic Sea area has been projected for different future storylines using scenario analysis consistent with global Shared Socio-economic Pathways (SSP) and scaling global drivers to primary regional drivers using a participatory approach to identify and describe regional drivers (Zandersen et al. 2019). Agricultural land use and livestock production will remain stable according to the baseline scenario of this analysis (Table A1) (Zandersen et al. 2019).

In an outlook for agriculture and food markets in EU member states, the modelled trends for crop, meat and dairy production from 2018 to 2030 differed between products and countries (Salamon et al. 2019). For the EU member states surrounding the Baltic Sea, the total production of crops included in the analysis (wheat, barley, corn, rapeseed, sunflower seed) is expected to remain stable (0.2% increase), beef and pork markets are estimated to decrease by 8% and3 %, respectively, and poultry markets are estimated to increase (7%). Milk production has been estimated to decrease, whereas production of other dairy products (butter, cheese, milk powder) is estimated to increase.

Development by country

In Estonia, agricultural activities are expected to increase by 2030 according to the national assessment for the MSFD Initial Assessment (IA), the middle of the road scenario in the BONUS project BALTICAPP deliverable D1.1 and an expert opinion in WWF report 'Future Trends in the Baltic Sea' (national assessment for MSFD IA, WWF 2010, Zandersen et al. 2016). Agriculture may intensify substantially also in other Baltic states (WWF 2010, Zandersen et al. 2016). In Poland, agricultural activity is expected to decrease based on the national response to HELCOM ESA data call (2018), whereas based on the middle of the road scenario of BONUS project BALTICAPP deliverable D1.1 and expert opinion in the WWF report 'Future Trends in the Baltic Sea', it will intensify substantially (WWF 2010; Zandersen et al. 2016). For Denmark, Germany and Sweden, no significant change in agricultural activities is expected (Swedish Agency for Marine and Water Management 2017, German Environment Agency 2019, Ministry of Environment and Food of Denmark 2020).

Prospects of the agricultural sector in Finland have been estimated with a modelling approach using an economic agricultural sector model called DREMFIA (Lehtonen 2015; Lehtonen & Niemi 2018, Aakkula et al. 2019). Based on the reference scenarios of these modelling exercises, meat production as a whole will decrease slightly or remain at the current level in 2030 and 2050 (Lehtonen 2015, Lehtonen & Niemi 2018, Aakkula et al. 2019). The direction of the change in milk and cereal production differs between the baseline/ reference scenarios of the different studies (Lehtonen 2015, Lehtonen & Niemi 2018, Aakkula et al. 2019). Based on the reference scenario in Aakkula et al. 2019, cultivated area will decrease 6% by 2030.

Product group specific predictions for all EU member countries are available in the outlook for agriculture and food markets in EU member states (Salamon et al. 2019).

Forestry

Regional development

In the northern parts of Europe, fellings are predicted to increase by around 7–12% from 2000-2012 levels to 2030 (Jonsson et al. 2018, UN 2011). Assuming that the increase is linear, harvests in the northern Europe would hence increase by around 4–6% from 2016 to 2030 (Table A2).

According to a model framework that fully integrates a European forest resource model and a global economic forest sector model, harvests in EU will increase by 7% from 2000-2012 levels to 2030 (Jonsson et al. 2018). According to the reference scenario of the model based European Forest Sector Outlook Study II, fellings are predicted to increase by 12% in Northern Europe, 13% in central Western Europe and 18% in central Eastern Europe from 2010 to 2030 (United Nations 2011). Consumption of forest products and wood energy are estimated to increase steadily in Europe during the next decade, with 0.5% annual increase in wood product consumption and 1.5% annual increase in fuel consumption, and the forest area available for wood supply is predicted to decrease slightly in the north and to increase slightly in more southern areas (United Nations 2011).

Development by country

Based on the national assessments for the MSFD IA, forestry will remain stable in Estonia (national assessment for MSFD IA) and Sweden (HELCOM ESA data call 2018). The national development trends have not been assessed for other countries as part of the national MSFD IA. Forestry in Sweden was estimated to remain stable also in the assessment of the state of the Swedish marine areas by the Swedish Agency for Marine and Water Management (2017). In Finland, based on the reference scenario of a modelling study, annual fellings would increase by 12% till around 2030 from the levels in 2015-2024, after which they would remain stable until 2050 (Aakkula et al. 2019).

Fish and shellfish harvesting

Regional development

There are no major changes expected for fishing activities in the Baltic Sea area. According to the baseline scenario of an analysis with different future storylines, the amount of fish caught for human consumption would slightly decrease, whereas amount caught for feed for aquaculture would slightly increase (Zandersen et al. 2019) (Table A3). Depending on the future scenario, fish demand may slightly decrease (Zandersen et al. 2019).

According to ICES, most of the Baltic Sea fish stocks with reference points are fished at or below F_{MSY} (fishing mortality consistent with achieving Maximum Sustainable Yield, MSY), but some stocks, including sprat, eastern and western cod, herring stocks in the central and western Baltic, plaice in ICES subdivisions 21–23, and sole in ICES subdivisions 20–24, are exploited above the F_{MSY} (ICES 2019a). Lowering the fishing quotas would first decrease fishing activity, but fisheries might later increase as the populations recover (WWF 2010). For the Gulf of Finland and the Archipelago Sea, fishing has been predicted to stay at the current level by 2050 in the reference scenario of a modelling study (Pöntynen & Erkkilä-Välimäki 2018).

Development by country

Based on the national assessment for the MSFD IA, commercial fishing is predicted to increase in Finland and decrease in Lithuania from the current levels to 2030, whereas for Denmark, Estonia, Latvia and Poland no significant changes in fishing are anticipated. In Sweden, fishing was predicted to decrease based on the national response to the HELCOM ESA data call (2018), but it was estimated to remain stable until 2030 in the assessment of the state of the Swedish marine areas by Swedish Agency for Marine and Water Management (2017). According to ICES advice in 2019, there should be zero catch of eastern Baltic cod from the stock in ICES subdivisions 24-32 in 2020, when precautionary approach is taken, which will likely affect the development of fishing in near future in part of the Contracting Parties (ICES 2019C).

Past development trend

In the ICES Baltic Sea Ecoregion, the nominal fishing effort (kW days at sea) decreased approximately 50% from 2004 to 2012 (ICES subdivision 23; ICES 2019a). The total number of days that the EU fishing fleet spends in the Baltic Sea has decreased in recent years. The number of days at sea was 32% less in 2017 compared to 2008 (STECF 2019). In 2014, 2015 and 2016, the number of days spent at sea were 9%, 21% and 23% less than in 2008 (STECF 2016, 2017, 2018a). Based on these data, fishing effort in the Baltic Sea has decreased on average 1.5 – 6% per year for the past 10 to 15 years. Fishing mortality has also decreased since the early 2000s, based on fishing mortalities against maximum sustainable yields (MSY) (for stocks with defined MSY reference points; ICES 2019a).

Marine aquaculture

Regional development

Marine aquaculture is projected to increase in the Baltic Sea region (Table A4). Marine aquaculture is predicted to grow at a medium rate, according to the reference scenario of long-term analyses (Zandersen et al. 2019). For the Gulf of Finland and the Archipelago Sea, aquaculture has been predicted to grow by 2050 in the reference scenario (Pöntynen & Erkkilä-Välimäki 2018). At the European level, the overall aquacultural production in marine and brackish waters has been slightly declining in volume but growing in value (European Commission 2012). Prospects are strong for algae growing (European Commission 2012).

Development by country

Marine aquaculture is predicted to increase in Estonia, and in Sweden there are plans to increase aquaculture (national assessments for the MSFD IA, Swedish Agency for Marine and Water Management 2017). In Denmark and Germany, no significant changes in marine aquaculture are predicted by 2030 (German Environment Agency 2019, Ministry of Environment and Food of Denmark 2020), and in Finland, marine aquaculture is predicted to decrease in the future (HELCOM ESA data call 2018). In Latvia, Lithuania and Poland there is currently no marine aquaculture, and its development in the future, although probable, is rather uncertain (AKTiiVS 2018, Lithuanian MSFD IA 2019, Ministry of Maritime Economy and Inland Navigation of Poland 2020). According to the WWF report 'Future Trends in the Baltic Sea', no increase in aquaculture is expected in Estonia, Latvia and Lithuania due to low number of suitable sites and in Sweden due to concerns on the impacts on environment, whereas for Denmark and Finland where attitudes are more positive, increase in aquaculture is more likely (WWF 2010).

Past development trend

In the Baltic Sea, marine aquaculture mainly takes place in Denmark, Finland and Sweden (HELCOM 2018a, WWF 2010). In addition, there is one finfish and one shellfish farm In Germany, whereas for other countries, production can be assumed to be non-existent (HELCOM 2018a). In Denmark, marine aquaculture production can be attributed to the Baltic Sea, as the production of dominant species for marine aquaculture, rainbow trout and mussels, are located in the Baltic Sea and fjords along the coast of Jutland (STECF 2018b).

The weighted average marine aquaculture production in Denmark, Finland and Sweden during the past ten years (2008-2017) was 29% higher than in the ten-year period before (1998-2007) (data in FAO 2019a-c). From 2006 to 2015, the weighted marine aquaculture production in Denmark, Finland and Sweden has increased about 3% per year (linear trend, R^2=0.60).

Marine shipping

Regional development

Ship traffic is likely to increase both at the intra- and extra-European scale due to global population growth, economic growth and globalization (Baltic LINes 2016). The growth in marine shipping could be strengthened by a modal shift of transport from road to sea, laid down in the European Commission White Paper "Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system" (Baltic LINes 2016, Fridell et al. 2016).

Similarly, marine shipping is expected to increase also in the Baltic Sea area (Table A5; e.g. Baltic LINes 2016, 2018, HELCOM 2018c, baseline scenario in Zandersen et al. 2019). The marine shipping has been estimated to grow 8% in 15 years (2015-2030) (Baltic LINes 2018). Based on the reference scenario of a modelling study, the number of ships will increase 0.2% per year from 2020 to 2030 (Fridell et al. 2016).

Cargo ships are the most numerous ships in the Baltic Sea, accounting for approximately half of the total number of ships, and together with container ships and tankers, they account for 74% of the total number of ships in the Baltic Sea (HELCOM 2018c). The cargo volume has been predicted to grow 2% per year from 2020 to 2030 (Fridell et al. 2016). Also, according to stakeholder views, most significant growth is expected in cargo volume, whereas the number of ships is less likely to rise (Baltic LINes 2018). Similarly, a 30% increase has been predicted for port throughput in the Baltic Sea in 2010-2030 (Baltic Port Organization 2012).

A strong increasing trend has been predicted for the demand on global cruise industry, and Baltic Sea is expected to benefit from this development (EC 2012). An annual increase of 1% is expected for cruises, whereas no increase is expected for total passenger traffic (BAU scenario in Fridell et al. 2016).

The increase in maritime traffic is expected to be most notable in the Gulf of Finland, due to increase in cargo and tanker shipping between the ports in the Gulf of Finland and ports within other Baltic Sea basins and outside the Baltic Sea (HELCOM 2018c). Both freight transport and passenger transport are predicted to increase in the Gulf of Finland (Pöntynen & Erkkilä-Välimäki 2018).

Development by country

For Russia, high increases in commercial, cargo and tanker shipping are expected (Baltic LINes 2018, HELCOM 2018c). Based on national responses to the HELCOM ESA data call (2018), shipping will increase in Estonia, Finland, Poland and Sweden. The performance of Polish ports has recently increased, which is expected to be reflected in the commercial shipping (Baltic LINes 2018). For Latvia, either growth or no significant change is expected, and for Denmark and Lithuania no significant change is expected.

Marine transport infrastructure

Regional development

It is estimated that marine transport infrastructure in the Baltic Sea region will increase (Table A6). The general growth of shipping is expected to result in growth of the ports, especially the largest ones (Baltic LINes 2018, WWF 2010). The port throughput is predicted to increase in the Baltic Sea region by 30% from 2010 to 2030 (Baltic Port Organization 2012). It is further expected that infrastructure for liquefied natural gas (LNG) will expand in Europe, and new infrastructures will lead in specialization and enlargement of ports (Baltic LINes 2018). According to WWF Baltic Ecoregion Programme (2010), the number of ports is not expected to change.

In the Gulf of Finland, ship building, warehousing, storage, building of boats and dredging are all estimated to increase moderately. Most cargo ports are estimated to grow (Pöntynen & Erkkilä-Välimäki 2018).

Development by country

Marine transport infrastructure is predicted to grow in most countries surrounding the Baltic Sea (HELCOM ESA data call 2018, Baltic LINes 2018). According to Baltic LINes report 2018, the growth in main ports of Estonia, Finland, Latvia, Lithuania, Poland and especially Russia is expected to be more pronounced than in ports of Germany, Denmark and Sweden. The main ports where offshore development and LNG developments are expected are situated in Estonia, Finland, Latvia, Lithuania, Poland, Russia and Sweden (Baltic LINes 2018).

Tourism and leisure activities

Regional development

Tourism is expected to grow in Europe by 2-3% per year in the long term (Table A7; European Commission 2012). Assuming this growth rate, tourism would increase by 30-40% from 2016 to 2030. Several sectors under tourism are increasing in Europe and in the Baltic Sea region: Cruise industry in Europe has been growing 12% per year in recent years (Fridell et al. 2016, WWF 2010), and the number of cruise ships in the Baltic Sea is predicted to increase 1% per year (reference scenario; Fridell et al. 2016). Leisure boating is also expected to increase in Europe and in the Baltic Sea region (Baltic LINes 2016, Baltic LINes 2018, WWF 2010), with an annual increase of 5-6% in the EU (WWF 2010). Recreational fishing is increasing steadily (WWF 2010).

Increase in tourism on the whole is expected also for the Gulf of Finland and Archipelago Sea (Pöntynen & Erkkilä-Välimäki 2018).

Development by country

Tourism is expected to grow in all Contracting Parties that have provided a national response regarding the topic (Table A7; HELCOM ESA data call 2018, national MSFD IA). Based on stakeholder views, cruise ship traffic is expected to grow especially in the already established cruise business ports in St. Petersburg, Tallinn and Helsinki, Archipelago Sea, Stockholm and Copenhagen (HELCOM 2018c). There may be growth also in newer destinations, e.g. in Bothnian Sea and Bay including The Quark area, which will, however, take time (HELCOM 2018c).

Offshore wind energy production

Regional development

Offshore wind energy production is expected to grow notably in the Baltic Sea region in the coming decades (Baltic LINes 2019, European Commission 2012, HELCOM 2018a, Hüffmeier & Goldberg 2019, Pöntynen & Erkkilä-Välimäki 2018, WWF 2010) (Table A8). Estimates for the increase in capacity by 2030 range from 130% to 390% based on the approved and planned turbines, turbines under construction and the intermediate (central) scenario by Baltic LINes project (HELCOM 2018a, Hüffmeier & Goldberg 2019, WWF 2010). In the Baltic LINes project, the uncertainty in the increase in offshore wind power capacity was considered to be low, based on the relatively low range between low (300%), intermediate (390 %) and high (640%) scenarios (Hüffmeier & Goldberg 2019). The predicted relative increase in national areas (territorial and EEZ) covered by offshore wind farms is in the same scale, being 260% in low, 350% in intermediate and 580% in high scenario (Hüffmeier & Goldberg 2019).

Not all experts interviewed for the European Commission Blue Growth report (2012) considered offshore wind production to grow so fast, as they identified various constraints that would need to be overcome and various conditions to be fulfilled, such as modest or strong increase in fossil fuel prices.

The whole energy sector is expected to increase in the Gulf of Finland area, with second largest growth in wind energy production (Pöntynen & Erkkilä-Välimäki 2018).

Development by country

Currently, offshore wind energy production takes place in Denmark, Finland, Germany and Sweden. According to all scenarios (low, intermediate, high) of the Baltic LINes project report, offshore wind power capacity is expected to be developed or increase in all Baltic Sea countries in the long term, and to be established in all Baltic Sea countries except Latvia already by 2030 (Hüffmeier & Goldberg 2019). Quantitative estimates for changes in capacity and area covered by offshore wind farms are available in the report. According to the national responses, offshore wind energy production is expected to grow in most countries that provided information on the topic (Table A8; HELCOM ESA data call (2018), MSFD IA). For Sweden, no significant increase by 2030 is expected according to the national response to HELCOM ESA data call (2018) and the assessment by Swedish Agency for Marine and Water Management (2017).

Urban sewage water systems

This section includes background information and scenarios for the development of urban sewage water systems related to wastewaters. The effect of improving wastewater treatment is included in the effectiveness of measures part of the SOM analysis, and this covers only the changes in the extent of the activity (i.e. urban sewage water).

Regional development

In scenario analyses extending Shared Socio-economic Pathways to the Baltic Sea (Zandersen et al. 2016, 2019), changes in wastewater treatment activity vary depending on the future scenario. In the reference scenario, the sewage sector is expected to increase in the most densely populated areas together with urbanization.

Development by country

Based on the national information, wastewater treatment and disposal are expected to remain on the current level in Lithuania (MSFD IA) and Denmark (Ministry of Environment and Food of Denmark 2020). In Sweden, wastewater treatment and disposal are expected to show no significant trends based on the national response to HELCOM ESA data call (2018), but to increase as a result of population increase according to the Swedish Agency for Marine and Water Management (2017). No national assessments could be obtained for other countries.

Predicted changes in population and connectivity of population to collecting systems for urban wastewater

The main factors influencing changes in the size of the urban sewage sector are changes in population and number of inhabitants with connection to urban wastewater collection systems. The urban sewage activity increases with increasing population as well as with increasing number of inhabitants with connection to urban wastewater collection systems. It should be noted that an increase in the share of inhabitants connected to urban wastewater systems decreases the input of untreated wastewaters to the environment and hence reduces the overall pressure from wastewaters. However, this effect is accounted for in other components of the SOM analysis (nutrient inputs from scattered dwellings).

Population changes from 2010 to 2030 have been predicted by the United Nations (2019). Based on the medium fertility variant of the population prospects, the population change in Baltic Sea countries is predicted to range from 13% decrease in Latvia and Lithuania to 7% increase in Sweden from 2016 to 2030 (Table A9).

Connection rate of population to urban wastewater treatment system ranges from 75% to 97% in the Baltic Sea countries that are also EU member states (European Environment Agency 2017).[4] The future changes in the connection rate were analysed based on requirements of the EU Urban Waste Water Treatment Directive (UWWTD) and projected urbanisations trends assumed to increase population connected to urban wastewater collection systems. The UWWTD states that all agglomerations of over 2000 population equivalent (PE) must be provided with collecting systems for urban wastewater (Article 3; Council Directive 91/271/EEC). The degree of compliance of providing the wastewater collection systems was 100% in most of the Baltic Sea countries that are EU member states (Table A9; European Commission 2017), except Poland and Estonia where the degree of compliance was 92% and 97% in 2014, respectively. The 100% compliance in 2030 is assumed for these two countries. This would increase the urban sewage water activity but decrease the release of untreated sewage water

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[4] Connection rate to urban wastewater systems (data for 2015): 97 % of the population in Denmark and Germany, 86 % in Finland and Sweden, 75 % in Estonia, Latvia, Lithuania and Poland.

to the environment and hence positively contribute to the state of coastal waters. This effect is covered in other parts of the SOM analysis.

The connection rate is also affected by urbanization, which is projected to range from 0.14% to 0.41% per year in the Baltic Sea countries (Average annual rate of change of the percentage urban; United Nations 2018).

Table A1. Predicted future development of **agriculture** in the Baltic Sea region (summary of the literature and information review results). Categories for future changes: Increasing ➚, Decreasing ➘, No significant change ➔, Trend differs between products **➚➘,** Uncertain/ Contradictory **?**. The years for which the development has been predicted are in brackets.

Source	**HELCOM ESA data call 2018 and national MSFD IA**	**Other national sources**	**Salamon et al. 2019** [7]	**WWF 2010**	**Zandersen et al. 2016**	**Zandersen et al. 2019**	**Summary**
Based on	national assessments (for MSFD IA)	various sources	AGMEMOD outlook, model, expert feedback	Expert view	Middle of the road scenario of the analysis, consistent with global SSPs, participatory approach	Baseline scenario of the analysis, consistent with global SSPs, extrapolated to Baltic Sea, participatory approach	
Baltic Sea			➚➘ -8% – 7% **(2020-2030)**			**➔ long-term**	**➚➘ (2030)**
DK		**➔ (2030)**[1]			**➔ long-term**		**➔ (2030)**
EE	**➚ (2030)**			**➚ (2020)**	**➚ long-term**		**➚ (2030)**
FI	**(➘** regulating service to mitigate nutrient input from agriculture)	➚➘ -7% – 7% (2020-2030)[2] ➚➘ -6% – >10% (2012-2025)[3] ➘ slightly (2050)[4]			**➔ long-term**		**➚➘ (2030)**
DE		**➔ (2030)**[5]		**➘ (2020)**	**➔ long-term**		**➔ (2030)**
LV				**➚ (2020)**	**➚ long-term**		**➚ ?**
LT				**➚ (2020)**	**➚ long-term**		**➚ ?**
PL	**➘ (2020)**			**➚ (2020)**	**➚ long-term**		**➚➘ ?**
RU							Not enough information
SE	**➔ (2030)**	**➔ (2030)**[6]			**➔ long-term**		**➔**

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020 (2) Based on reference scenario in Aakkula et al. 2019; (3) Based on reference scenario in Lehtonen & Niemi 2018; (4) Based on baseline scenario in Lehtonen 2015; (5) German Environment Agency (information provided in November of 2019); (6) Swedish Agency for Marine and Water Management 2017; (7) Product specific projections for all EU member countries are available in the outlook for agriculture and food markets in EU member states (Salamon et al. 2019).

Table A2. Future development trends of **forestry** in Europe and the Baltic Sea region (summary of the literature and information review results).

Categories for future changes: Increasing ➚, Decreasing ➘, No significant change ➔, Uncertain **?**. The years for which the development has been predicted are in brackets. In the summary column, the quantitative estimates for 2016-2030 have been derived from values in the references for each region or country, assuming that the change is linear.

Reference	**HELCOM ESA data call 2018 and national MSFD IA**	**Other national sources**	**Jonsson et al. 2017**	**UN 2011 European Forest Sector Outlook Study II**	**Summary**
Data based on	national assessments (for MSFD IA)		BAU scenario of a model framework fully integrating a European forest resource model and a global economic forest sector model.	Reference scenario of analyses with a range of models to cover the whole sector; based on official data supplied to UNECE/FAO and other organisations by national correspondents.	
EU			**harvests ➚ 7% (2012-2030)**		**harvests ➚ 5% (2016-2030) [3]**
Baltic Sea				**fellings ➚** N-Europe 12%, central W Europe 13%, central E Europe 18% **(2010-2030)**	**fellings ➚ 9% (2016-2030) [3] assuming N-Europe values**
DK					Not enough information
EE	**➔ (2030)**				**➔ (2030)**
FI		**fellings ➚ 12% (from 2015-2024 levels to ~2030) [1]**			fellings ➚ 12% (~2016-2030)
DE					Not enough information
LV					Not enough information
LT					Not enough information
PL					Not enough information
RU					Not enough information
SE	**➔ (2030)**	**➔ (2030) [2]**			**➔ (2030)**

(1) Based on LULUCF reference scenario in Aakkula et al. 2019; (2) Swedish Agency for Marine and Water Management 2017; (3) The increase in harvests till 2030 comparing to the 2020 level has been estimated from the projected increase from 2000-2012 to 2030 assuming a linear increase.

Table A3. Future development trends of commercial **fishing** in the Baltic Sea region (summary of the literature and information review results).

Categories for future changes: Increasing ➚, Decreasing ➘, No significant change ➔, Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Other national sources**	**Zandersen et al. 2019**	**WWF 2010**	**Pöntynen, R. & Erkkilä-Välimäki, A. 2018**	**Summary**
Data based on	national assessments (for MSFD IA)		Baseline scenario in analysis consistent with global SSPs, participatory approach	fishing quotas recommended by ICES	BAU scenario built with Delphi method, expert opinions	
Baltic Sea			**SLIGHT CHANGES** **for human consumption ➘ (long-term)** **for feed for aquaculture ➚ (long-term)**	**If ICES fishing quotas are accepted, first ➘ followed by ➚**	Gulf of Finland and Archipelago Sea **➔ (2050)**	**➔?**
DK		**➔ (2030)**[1]				**➔ (2030)**
EE	**➔ (2030)**					**➔ (2030)**
FI	**➚**					**➚**
DE						Not enough information
LV	**➔ (2030)**					**➔ (2030)**
LT	**➘ (2030)**					**➘ (2030)**
PL	**➔ (2020)**					**➔ (2020)**
RU						Not enough information
SE	**➘ (2030)**	**➔ (2030)** [2]				**➔ ? (2030)**

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020; (2) Swedish Agency for Marine and Water Management 2017.

Table A4. Future development trends of **aquaculture** in the Baltic Sea region (summary of the literature and information review results). Categories for future changes: Increasing ↗, Decreasing ↘, No significant change → Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Other national sources**	**Zandersen et al. 2019**	**WWF 2010**	**Pöntynen, R. & Erkkilä-Välimäki, A. 2018**	**Summary**
Data based on	national assessments (for MSFD IA)	various sources	scenario analysis, consistent with global SSPs, participatory approach	Suitable sites, attitude, plans	Delphi method, expert opinions	
Baltic Sea			↗ **medium rate**		GoF and Archipelago Sea ↗	↗ **medium rate**
DK		→ **(2030)**[1]		↗**?**		→ **(2030)**
EE	↗ **(2030)**			→**?**		↗ **(2030)**
FI	↘			↗**?**		**?**
DE		→ **(2030)**[2]				→ **(2030)**
LV	? **(2030)**			→**?**		**?**
LT	? **(2030)**			→**?**		**?**
PL		? **(2030)**[3]				?
RU						Not enough information
SE	↗ **(2030)**	↗ **(2030)**[4]		→**?**		↗ **(2030)**

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020, (2) German Environment Agency (information provided in November 2019), (3) Ministry of Maritime Economy and Inland Navigation of Poland (information provided in March 2020), (4) Swedish Agency for Marine and Water Management 2017

Table A5. Future development trends of **marine shipping** in Europe and the Baltic Sea region (summary of the literature and information review results). Note. In the summary column, the predicted development in the Baltic Sea region is based on the value from Baltic LINes 2018 and on the annual increase in number of ships and cargo volume in Fridell et al. 2016, extrapolated to cover the years 2016-2030. Categories for future changes: Increasing ↗, Decreasing ↘, No significant change →, Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Other national sources**	**Baltic LINes 2016**	**Baltic LINes 2018**	**Pöntynen & Erkkilä-Välimäki 2018**	**Zandersen et al 2019**	**EC 2012 Third Interim report**	**Fridell et al. 2016 (SHEBA)**	**WWF 2010**	**HELCOM 2018c**	**Baltic Port Organization (2012)**	**Summary**
Based on	national assessments (for MSFD IA)		Reports, e.g. from relevant projects	extrapolation of current growth, scientific and statistics, stakeholder opinions	Delphi method, expert opinions	Baseline scenario of analysis, consistent with global SSPs, participatory approach	analyses using statistics and assumptions	BAU scenario in SHEBA, literature survey on existing scenarios, stakeholder consultation, Workshop	Swedish Environmental Protection Agency, UTU, VTT	Delphi, expert evaluation		
Europe			↗									↗
Baltic Sea				↗ 8% (2015-2030)	GoF and Archipelago Sea ↗	↗ long-term	↗ Cruise industry ↗ 3-4 % short sea shipping ↗ size of ships	(2020-2030) ↗ total fleet capacity 1%a^{-1}, ↗ Number of ships 0.2%a^{-1} ↗ cargo volume 2% a^{-1}	no of ships ↗ 100% ↗ ship volume, cruises, oil shipping (2010-2030)	↗ GoF most, cargo and tanker	↗ Port throughput 30% (2010-2030)	↗ 3-28% (2016-2030)
DK		**→ (2030)**[2]										**→ (2030)**
EE	**↗ (2030)**											**↗ (2030)**

FI	**↗**											**↗**
DE												Not enough information
LV	**→↗**[1] **(2030)**											**↗? (2030)**
LT	**→ (2030)**											**→ (2030)**
PL	**↗ (2030)**			**↗**								**↗ (2030)**
RU				**↗ (2030)**						**↗**		**↗ (2030)**
SE	**↗ (2030)**	**↗ (2030)**[3]										**↗ (2030)**

(1) Different trend for various cargo types; (2) Information provided by Ministry of Environment and Food of Denmark in February 2020; (3) SwAM 2017.

Table A6. Future development trends of **marine transport infrastructure** in the Baltic Sea region (summary of the literature and information review results).

Categories for future changes: Increasing ↗, Decreasing ↘, No significant change → Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Other national sources**	**Baltic LINes 2018**	**Pöntynen & Erkkilä-Välimäki 2018**	**WWF 2010**	**Baltic Port Organization (2012)**	**Summary**
Data based on	national assessments (for MSFD IA)		extrapolation of current growth, scenario	Delphi method, expert opinions	Baltic Port Organization, HELCOM		
Baltic Sea			**↗ medium and large ports grow 50% (2010- 2030) → Number of ports**	**GoF ↗ moderate ship building warehousing storage boat building dredging**	↗	Port throughput ↗ 30% (2010-2030)	**↗ 21% (2016-2030)**
DK		→ (2030)[2]					→ (2030)
EE	↗ (2030)		↗				↗ (2030)
FI	↗		↗				↗
DE							Not enough information
LV	→↗ (2030) [1]		↗				↗?
LT	↗ (2030)		↗				↗ (2030)
PL	↗ (2030)		↗				↗ (2030)
RU			↗				↗?
SE	↗ (2030)	↗ (2030)? [3]	↗				↗ (2030)

(1) Different trend for various cargo types, (2) Information provided by Ministry of Environment and Food of Denmark in February 2020, (3) SwAM 2017

Table A7. Development of **tourism and leisure** activities in the Baltic Sea region (summary of the literature and information review results). In the summary column, the increase in tourism in Europe in 2016-2030 is based on the annual increase in tourism provided in European Commission 2012 Third Interim report.

Categories for future changes: Increasing ↗, Decreasing ↘, No significant change → Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Baltic LINes 2016**	**Baltic LINes 2018**	**Pöntynen & Erkkilä-Välimäki 2018**	**EC 2012 Third Interim report**	**Fridell et al. 2016 (SHEBA)**	**WWF 2010**	**HELCOM 2018c**	**Other national sources**	**Summary**
Based on	national assessments (for MSFD IA)	Reports, e.g. from relevant projects	extrapolation of current growth	Delphi method, expert opinions	analyses using statistics and assumptions	literature survey on existing scenarios, stakeholder consultation, Workshop	Baltic Port Organization, HELCOM	Delphi, expert evaluation		
Europe					↗ 2-3% a^{-1} in north more?		↗ leisure boating 5-6% a^{-1}			↗ 30-40% (2016-2030)
Baltic Sea		↗ leisure boating ↗ cruise ships	↗ leisure traffic	↗ (2050) GoF & Archipelago Sea		↗ cruise passenger, number of fleet 1% a^{-1} GT 0.4 %	↗ tourism, Recreational fishing, boating 5-6% a^{-1}, cruises 12% a^{-1}	↗ cruises		↗ cruises, number of fleet 14% (2016-2030)
DK								↗ cruises	↗ (2030)[1]	↗ (2030)
EE	↗ (2030)							↗ cruises		↗ (2030)
FI	↗							↗ cruises		↗
DE										Not enough information
LV	↗ (2030)									↗ (2030)
LT	↗ (2030)									↗ (2030)
PL	↗ (2020)									↗ (2020)
RU								↗ cruises		↗
SE	↗ (2030)							↗ cruises	↗ (2030)[2]	↗ (2030)

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020; (2) SwAM 2017

Table A8. Development of **offshore wind energy production** in Europe and the Baltic Sea region (summary of the literature and information review results). In the summary column, increase in offshore wind energy capacity in the Baltic Sea region is based on the information in WWF (2010) and HELCOM (2018b) and the most likely scenario in Hüffmeier & Goldberg (2019). Quantitative estimates for increase in capacity (MW) and area covered by wind farms per country are available in Hüffmeier & Goldberg (2019).

Categories for future changes: Increasing ➚, Decreasing ➘, No significant change ➔ Uncertain **?**. The years for which the development has been predicted are in brackets.

	HELCOM ESA data call 2018 and national MSFD IA	**Other national sources**	**Hüffmeier & Goldberg 2019**	**Pöntynen & Erkkilä-Välimäki 2018**	**EC 2012 Third Interim report**	**HELCOM 2018a**	**WWF 2010**	**Summary**
Data based on	national assessments (for MSFD IA)		Most likely scenario; an average of three of published scenarios, literature study, various GIS data, national experts	Delphi method, expert opinions	analyses using statistics and assumptions		Based on Planned farms	
Europe					**➚ (2010-2020)**			**➚**
Baltic Sea			**➚ capacity (MW) 390%, area 350% (2017-2030)** **➚ (2030->2050)**	**➚ GoF**		**➚ 290% capacity when ones approved and under construction in function**	**➚ capacity and no of farms 130% (2020-2030)**	**➚ capacity 130-390% (~2016-2030)** **area 350%**
DK		**➚ (2030)[1]**	**➚ MW 101% (2017-2030)**					**➚ (2030 & 2050)**
EE	**➚ (2030)**		**➚ 0 → 430 MW (2017-2030)**	**➚**				**➚ (2030 & 2050)**
FI	**➚**		**➚ MW 400% (2017-2030)**					**➚ (2030 & 2050)**
DE		**➚ (2030)[2]**	**➚ MW 408% (2017-2030)**					**➚ (2030 & 2050)**
LV	**➚ ? (2030)**		**➚ (2050), no development by 2030**					**➚ ? (2017-2030)**
LT	**➚ (2030)**		**➚ 0 → 50 MW (2017-2030)**					**➚ (2030 & 2050)**

PL			**↗ 0 → 1730 MW (2017-2030)**						**↗ (2030 & 2050)**
RU			**↗ 0 → 430 MW (2017-2030)**						**↗ (2030 & 2050)**
SE	**→ (2030)**	**→ (2030)[3]**	**↗ MW 269% (2017-2030)**						**→ ? (2030)**

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020: (2) German Environment Agency (information provided in November of 2019): (3) Swedish Agency for Marine and Water Management 2017

Table A9. Predicted development of **sewage water systems** in the Baltic Sea region and factors indicating its future development (summary of the literature and information review results). Categories for future changes: Increasing ➚, Decreasing ➘, No significant change ➔ Uncertain **?**, UWWTD = Urban wastewater treatment directive. The years for which the development has been predicted are in brackets. In the summary column, both the predicted population growth and the degree of compliance with Urban Waste Water Treatment Directive article 3 are taken into account for individual countries, if there is no national information provided. It is assumed that the degree of compliance would be 100% for all EU countries by 2030.

Source	**HELCOM ESA data call 2018 and national MSFD IA**	**Other national sources**	**Zandersen et al. 2016**	**Zandersen et al. 2019**	*Population growth, United Nations 2019*	*Degree of compliance with UWWTD Article 3 in % of subjected load, European Commission 2017*	Urbanization, United Nations 2018	**Summary**
Based on	national assessments (for MSFD IA)	based on population growth	Middle of the road scenario in analysis consistent with global SSPs, participatory approach	Baseline scenario in analysis consistent with global SSPs, participatory approach	*Predicted population growth 2020-2030, medium fertility variant*	Degree of compliance in 2014	Predicted urbanization 2015-2030 (average annual rate of change of the urban by country)	
Baltic Sea			**➚ (in urban areas)**	**➚ (expansion in most densely populated areas)**				➚
DK		➔ (2030)[1]			*➚ 5% (2016-2030)*	100%	*➚ 2% (2016-2030)*	➔ *➚? (2030)*
EE					*➘ 5% (2016-2030)*	97%	*➚ 4% (2016-2030)*	➔ *➚? (2030)*
FI					*➚ 1% (2016-2030)*	100%	*➚ 1.5% (2016-2030)*	*➚? (2030)*
DE		➘ (2030) due to upgrading selected wastewater treatment plants [2]			*➘ 1% (2016-2030)*	100%	*➚ 2% (2016-2030)*	*? (2030)*
LV					*➘ 13% (2016-2030)*	100%	*➚ 3% (2016-2030)*	➘ *? (2030)*

LT	**→ (2030)**				↘ *13% (2016-2030)*	100%	↗ *5% (2016-2030)*	**→ (2030)**
PL					↘ *3% (2016-2030)*	*92%*	↗ *2% (2016-2030)*	↗ *? (2030)*
RU					↘ *3% (2016-2030)*		↗ *4% (2016-2030)*	*? (2016-2030)*
SE	**→ (2030)**	**↗ (2030)**[3]			↗ *7% (2016-2030)*	100%	↗ *4% (2016-2030)*	**↗ (2030)**

(1) Information provided by Ministry of Environment and Food of Denmark in February 2020: (2) German Environment Agency (information provided in November of 2019): (3) Swedish Agency for Marine and Water Management 2017

Annex B. Existing measures – measure type linkages

Excel containing the identified existing measures and their relationship to the measure types used in the SOM analysis. Available at the HELCOM ACTION project workspace.