# Sufficiency of existing measures for non-indigenous species in the Baltic Sea

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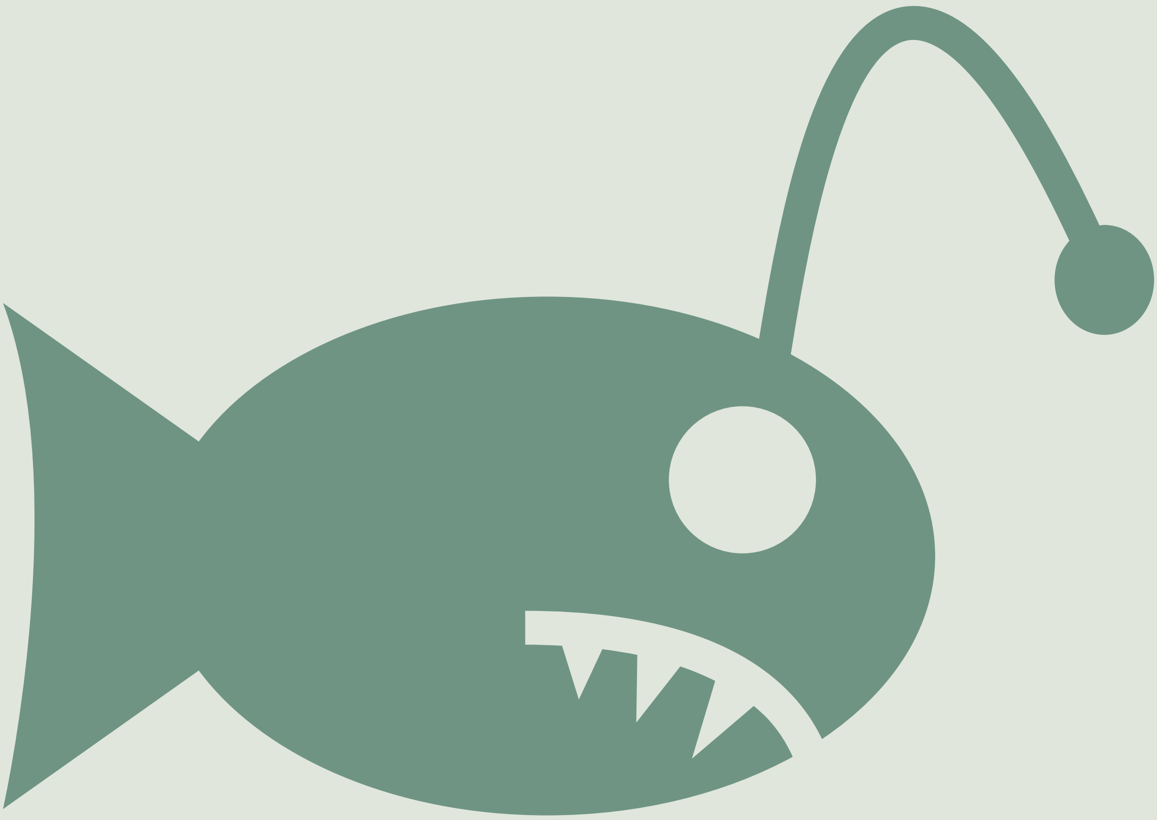

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# Sufficiency of existing measures for non-indigenous species in the Baltic Sea

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## Summary of main results

This analysis evaluates the projected reduction in the anthropogenic introduction of NIS, considering the effects of existing measures and changes in the extent of human activities.

Existing measures do not seem sufficient for achieving the HELCOM GES threshold value of no new introductions of non-indigenous species.

The projected reduction in the anthropogenic introductions of NIS is moderate, with some uncertainty of its magnitude.

State components most affected by the effects of NIS are: sandwich tern, common eider, flounder, and hard substrate epifauna dominated community.

Main activities contributing to the introduction of NIS are shipping (ballast water), activities and sources outside the Baltic Sea Region, and shipping (biofouling).

Measure types having the most impact on the introduction of NIS address shipping (ballast water, biofouling), and are related to the implementation and enforcement of the Ballast Water Management Convention, more stringent technical requirements and standards for ballast water and sediment management on ships, enforced installation and maintenance of anti-fouling system, and regionally harmonized in-water cleaning regulations. There is considerable uncertainty about the effectiveness of measure types in reducing the introduction of NIS.

The NIS analysis is highly focused on the Baltic Sea region and therefore treats human activities and introduction events in e.g. North Sea as outside the scope and control of the HELCOM countries. This complicates the assessment as the issue of natural secondary spread into the Baltic Sea can be a contributing activity that is not assessed (i.e. a NIS may enter the Baltic Sea as a new introduction but due to a nearby introduction not directly taking place in the HELCOM region itself), and inputs are assumed constant. Results should be interpreted with this and all other relevant assumptions in the analysis in mind.

# Introduction

## Report background

The sufficiency of measures (SOM) analysis assesses improvements in environmental state and reduction of pressures that can be achieved with existing measures in the Baltic Sea region, and whether these are sufficient to achieve good environmental status (GES). The analysis involves estimating the state of the marine environment in 2030, based on a starting point of 2016 (i.e. the latest HELCOM status assessment), and given measures in existing policies, their implementation status, and the projected development of human activities over time. The evaluation can be carried out compared to relevant and agreed HELCOM threshold values for GES, where available.

The main aim 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 with existing measures for the Baltic Sea. In addition, the analysis can indicate both thematically and spatially where new measures are likely needed.

The same overall approach has been applied across all topics included in the SOM analysis to ensure comparability and coherence of the results, while considering topic-specific aspects and making necessary adjustments. The main components of the analysis include assessing the contribution of activities to pressures, the effect of existing measures on pressures, the effect of development of human activities on pressures, and the effect of changes in pressure on environmental state. The SOM approach, model and data collection are described in detail in the methodology report.

The methodology for the SOM analysis is designed to accommodate the broad array of topics relevant in the HELCOM region and to enable a region-level analysis. It balances between state-of-the-art knowledge, availability of data, and advice taken onboard from various HELCOM meetings and bodies.

The data used in the SOM analysis have been collected using expert elicitation and by reviewing existing literature, model outputs and other data sources. Data availability varies substantially across topics and data components, which is reflected in the presentation of the methods and results in this report.

The SOM analysis presents the first attempt to quantify the effects of existing measures and policies on the environment and achieving policy objectives for various environmental topics in HELCOM and the Baltic Sea area. It is aimed at assessing the overall sufficiency of existing measures at the Baltic Sea level. The results are based mainly on expert elicitation, and thus they should be utilized appropriately. Due to the pioneering nature of the approach and variable data quality and availability in the SOM analysis, the findings do not provide conclusive answers on the need for new measures, but indicate likely gaps, and should thus also be reviewed in relation to the results of other assessments.

This topic report describes the analyses carried out and the results for the SOM analysis on non-indigenous species (NIS), providing detailed topic-specific information. First, it presents background information and describes the data and methods for addressing the topic in the SOM assessment, including relevant assumptions and challenges. Second, it presents and discusses the findings for each result component. Third, it provides discussion on the impacts of alternative assumptions and data, evaluates the quality and confidence of the analysis, and provides implications and future perspectives. The annexes contain detailed information on the data components, topic structure and expert surveys for the analysis, as well as supplementary results.

Similar topic reports have been prepared for all nine topics covered in the SOM analysis. In addition, the results are summarized in the main report and the full methodology is described in the methodology report.

## Topic background

Introduction of non-indigenous species (NIS) is acknowledged as one of the most important external drivers affecting structure and functions of marine ecosystems globally. NIS are considered to be one of the most important direct drivers of biodiversity loss and a major pressure on several types of ecosystems, with both ecological and economic impacts (MEA, 2005). In marine ecosystems, alien marine species may become invasive and displace native species, cause the loss of native genotypes, modify habitats, change community structure, affect food web properties and ecosystem processes, impede the provision of ecosystem services, impact human health, and cause substantial economic losses (Katsanevakis et al., 2014). The Baltic Sea is generally considered to be susceptible to invasions by NIS. Out of the total of 132 NIS and cryptogenic species recorded in the Baltic Sea, 59% have become established in at least one country. On average, each coastal country currently hosts 27 such species with 15% of the established species being found in at least 50% of the countries (Ojaveer et al., 2016; HELCOM, 2018).

## Description of non-indigenous species in the SOM assessment

NIS are considered in two distinct ways in the SOM analysis. The first is as the pressure input *Anthropogenic introductions of non-indigenous species,* which reflects the structure of the HELCOM indicator "Trends in arrival of new non-indigenous species" and MSFD criteria D2C1[1] (Figure 2). This pressure input has an established HELCOM GES threshold value, set at no new introductions of NIS or cryptogenic species (CS) to the Baltic Sea through human activities during a six-year assessment period. As the assessment is conducted using HELOCM Scale 1 assessment units, i.e. the Baltic Sea as one unit, only introductions of species previously absent from the Baltic Sea, i.e. primary introductions, are considered. For the latest HOLAS assessment period (2011-2016), 12 new primary introductions of NIS/CS were identified from the AquaNIS database (AquaNIS, 2015), indicating a not good status (HELCOM, 2018). The pressure input covered in the SOM analysis (*Anthropogenic introductions of non-indigenous species)* assesses the flow of NIS into the Baltic Sea but does not consider the effects of NIS once they are established.

[1] Marine Strategy Framework Directive criteria D2C1 – Primary: The number of non-indigenous species which are newly introduced via human activity into the wild, per assessment period (6 years), measured from the reference year as reported for the initial assessment under Article 8(1) of Directive 2008/56/EC, is minimised and where possible reduced to zero. Member States shall establish the threshold value for the number of new introductions of non-indigenous species, through regional or subregional cooperation.

The second aspect of NIS in the SOM model is the pressure *Effects of non-indigenous species*, which considers NIS effects after establishment (Figure 1). This component does not directly correspond to a HELCOM indicator or single MSFD criteria, but in the SOM analysis it holistically assesses NIS effects in the Baltic Sea via expert knowledge. There are very limited options for reducing the impact of established populations of NIS and eradication of established NIS populations in a marine setting is rare (Williams and Grosholz, 2008), and often impractical. This makes prevention of the introduction and spread of NIS the primary management target for this pressure. As such, measures targeting the effects of NIS are not evaluated in the SOM analysis (i.e. management and mitigation of existing populations), only measures targeting their introduction are assessed (i.e. prevention of new populations). However, the pressure affects a broad range of topics included in the SOM analysis, such as birds, fish, and benthic habitats. In the expert surveys on pressure-state linkages, this pressure could be selected as being significant to any of the state components and is thus included in the pressure-state assessment of the SOM analysis. No connection has been estimated between the pressure input of anthropogenic introductions and the effects of NIS in the SOM analysis due to the high uncertainty of the effects of a hypothetical NIS introduction, i.e. it is difficult to know the average impact of a new NIS in the Baltic Sea as the effects vary considerably depending on the species. However, reducing the number of new NIS introductions is almost certain to reduce the future effects of NIS.

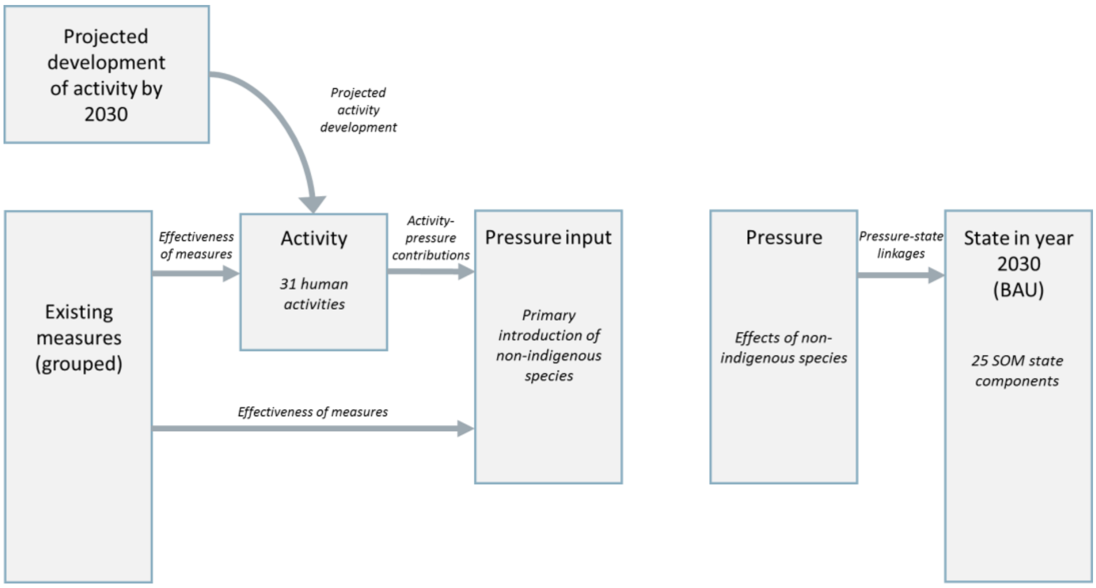


**Figure 1. Schematic of the SOM analysis for non-indigenous species.** The impacts of the pressure input (anthropogenic introductions of non-indigenous species) on the pressure (effects of non-indigenous species) have not been estimated within the SOM analysis.

# Methods and data

The section below includes an overview of any topic-specific methodologies. A full description of the general approach, methods and data collection for the SOM analysis is available in the methodology report. Note that the detailed results are presented for the most likely development of human activities and using the expert data on effectiveness of measures.

## Activity-pressure contributions

For *anthropogenic introduction of non-indigenous species*, reports of 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 shipping, 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 secondary spread into the Baltic Sea 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 (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 averages provide 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.

## Effectiveness of measures

Measure types (Annex 3) and structural relationships between the measure types and activities and pressure inputs (Annex 7) were designed by the SOM NIS Topic Team in collaboration with HELCOM ACTION WP6. The measure types were informed by the existing measures list (Annex 4) but were also designed to acknowledge the full breadth of potential measures.

For NIS, the effectiveness of measures survey structure comprised 19 unique measure types covering 4 activities. There was no duplication of measure types across activities. The exact list of measure types, and their grouping by activities and pressure inputs is shown in Annex 7. The effectiveness of measures survey itself is included as Annex 8.

Effectiveness of the measure types and links between the pressures and state components were determined using online expert surveys implemented in December 2019 – February 2020 with follow-up surveys conducted in the spring 2020. The expert pool consisted of the HELCOM/OSPAR Task Group on Ballast Water Management Convention Exemptions and nationally nominated experts. Additionally, the project received survey responses from experts not on the original invitation list; these responses were also included in the analysis. The full description of the methodology and data collection is available as part of the SOM methodology report.

## Projected reductions in pressures inputs

The calculation of the projected reduction is based on the activity-pressure contributions, effectiveness of measure types, links between existing measures and measure types, and projected development of human activities. Both the activity-pressure data and the effectiveness of measures data are at the Baltic Sea scale, and thus the result is presented at the Baltic Sea level.

The projected reductions account for the joint impacts across the measure types, as well as the spatial area where the pressure inputs can be reduced to avoid overestimating the pressure input reductions. Pressure reductions can be positive (pressure is reduced), negative (pressure is increased) or zero (no change in pressure), depending on the combined effect of existing measures and changes in the extent of human activities. When the reduction in pressure inputs from existing measures is larger than the increase from changes in human activities, pressure inputs are reduced.

## Topic-specific model structure, assumptions, and challenges

Outside of the modifications noted in the section Activity-pressure contributions, NIS has operated according to the standard SOM topic structure and did not generate any unique challenges.

## Overview of data

The SOM analysis for NIS evaluates the pressure reductions achievable by 2030, considering the effects of existing measures and future development of human activities.

Table 1 shows the origin and spatial resolution for the data components in the SOM analysis for NIS. Information on existing measures comes from literature reviews and was supplemented with relevant national measures by Contracting Parties, and development of human activities is based on existing literature, data and projections.

Estimates of the effectiveness of measures were collected both via expert surveys and a literature review. The aim of the literature review was to compile information from scientific articles and reports providing estimates on the effects of measures in reducing pressure inputs that could be used in the SOM analysis, 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 (see the methodology document, Annex 5 and Annex 6 for more information). For NIS, 50 effectiveness estimates from 18 studies were compiled. Out of these, 15 estimates from 6 studies could be included in the model due to data format requirements of the SOM analysis and a conservative approach to determining what estimates are applicable to the Baltic Sea region. Detailed results are presented using only the expert data, and the implications of using the literature data for the effectiveness of measures are reviewed in the discussion section. Scenarios for the development of human activities were based on existing information and projections for the Baltic Sea region, and pressure-state links were evaluated with expert elicitation.

The spatial resolution (level of detail) differs across the data components of the SOM analysis. All assessment areas are based on the 17 HELCOM scale 2 sub-basins and the assessment area ranges from the single Baltic Sea to individual sub-basins. However, for NIS, all the data is reported at the Baltic Sea scale (Table 1) because this is also the scale of the HELCOM indicator. When the topic of NIS interacts with other topics, e.g. birds, mammals, benthic habitats, smaller spatial scales may be used to reflect spatial variation in those topics.

**Table 1.** Data for NIS (more information on data collection is available in the methodology report)

| **Data component** | **Source of data** | **Spatial resolution** |
|---|---|---|
| Activity-pressure contributions | AquaNIS database | Whole Baltic Sea |
| Existing measures | Literature review, Contracting Parties | 17 sub-basins |
| Effectiveness of measures | Expert survey | Whole Baltic Sea |
| Development of human activities | Literature review, existing data and projections | Whole Baltic Sea |
| Pressure-state links | NA | NA |

## Development of human activities

In addition to existing measures, changes in the extent of human activities may affect pressure inputs over time. Four scenarios for future changes in human activities were developed: 1) no change, 2) low change, 3) moderate (most likely) change, and 4) high change. These alternative scenarios aim to capture uncertainties and variation in the future development of human activities. The results of the SOM analysis were estimated for each of the four scenarios to assess how the alternative assumptions on the development of human activities affects the findings. Detailed results are presented for the most likely development scenario, and implications of using the other scenarios on the results are reviewed in the discussion section.

The scenarios specify a percent change in each activity during the period of 2016–2030 based on existing information and projections from the Baltic Sea region. These development scenarios were made only for predominant activities in the Baltic Sea region, including agriculture, forestry, waste waters, (commercial) fish and shellfish harvesting, aquaculture, renewable energy production, tourism and leisure activities, transport shipping and transport infrastructure. Other activities are assumed to stay unchanged in the analysis of all topics. This means that only 9 of the 31 standard SOM activities have development scenarios in the SOM analysis. This results in varying influence of these scenarios on the results across topics, pressures, and state components, depending on the significance of the activities to the pressure inputs relevant to the topic.

The coverage of activities that contribute to the introduction of NIS in the development scenarios is rather high, around 60%. Development scenarios were made for shipping (ballast water, biofouling) and marine aquaculture, which are both expected to increase by 20% until 2030 in the most likely scenario. In the analysis, inland aquaculture is assumed to change similarly to marine aquaculture, as no separate development scenarios were made for it. Activities and sources outside the Baltic Sea Region and shipping infrastructure (canals) are assumed to stay constant until 2030. More information on the development scenarios and source materials for the projections are presented in section 9 of the methodology report.

The current situation with COVID-19 and its possible implications to the development of human activities is not reflected in the scenarios, 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 choosing the most likely scenarios for the development of human activities, which has been done based on currently available information.

# Results and interpretation

## Background

The SOM results are presented in the format of percent shares or probabilities. The main finding of the analysis is the probability to achieve GES or specific state improvements/pressure input reductions, taking into consideration the effects of existing measures and changes in the activities on pressure inputs. The contribution of activities to pressure inputs, the effect of measures on pressure inputs, and the significance of pressures to state components are presented as percent values (e.g. how many percent would the measure reduce the pressure input). Results are presented mainly in tables, which show the most likely (expected) values and standard deviations. Standard deviation is a way of showing the variation in the values. When it is high, values are spread over a wider range, and when it is low, values are closer to the most likely value. Figures and graphs presenting distributions are included in the annexes. They show the same results as the tables but allow either more detailed information or alternative visualisation of the results.

For the data that are based on expert surveys, the confidence rating gives the most common answer to experts' assessment of the confidence in their own survey responses on a low-moderate-high scale. More detailed information on how each result has been calculated is presented in a separate document.

This document presents the detailed results based on the expert-based data (survey responses). Literature data on the effectiveness of measures has been collected and included in an alternative model estimation. The impacts of using the literature data are evaluated in the discussion section. In the detailed results, the projected development of human activities is based on the most likely future development until 2030 (for details, see the methodology document), and the impacts of alternative scenarios on human activities are examined in the discussion section.

## Format of presentation

The format the results are reported in different ways (not presented, qualitative/semi-quantitative, quantitative) depending on the type of result and the number of participating experts. Further, for all results utilizing prior SOM results as input data, reporting is done at the most conservative standard used in the input data. In practice this means that if one input data point is reported as 'insufficient data', all results using that data point will also be reported as 'insufficient data'; similarly for qualitative/semi-quantitative data points. However, note that this standard is only applied in the case of data points actively used to calculate another result. For example, many measure types are hypothetical or otherwise not implemented in the Baltic Sea and therefore do not factor into results on projected pressure input reductions from existing measures. Insufficient data for such measure types (i.e. non relevant ones) does not affect reporting of other results that rely on data for effectiveness of measure types. Results that do not meet the data standards described here, and in greater detail below, are marked with 'insufficient data' in the report. All the data components for NIS meet the thresholds for fully quantitative presentation.

For results concerning required pressure reductions and significance of pressures to state components, results with 2 or fewer respondents are not reported; results with 3 to 4 respondents will be either not reported, or qualitatively/semi-quantitatively reported based on feedback from the SOM topic teams or other HELCOM expert body; results with 5 or more respondents are reported quantitatively. This standard allows flexibility for reporting on assessments that are of spatially limited areas and therefore have fewer experts available to survey, while also being somewhat conservative in reporting fully quantitative results. It affects how the results on which state components are affected by NIS are presented.

For expert-based effectiveness of measures results, measure types with 5 or more respondents are reported quantitatively and those with 4 or fewer respondents are listed as having insufficient data. This criterion is met for NIS.

The activity-pressure data comes from the AquaNIS database and is thus presented in a quantitative format.

## What are the reductions in pressure inputs from existing measures? Are measures sufficient in achieving GES?

The HELCOM GES threshold is set at no new introductions of NIS or CS to the Baltic Sea through human activities during a six-year assessment period. This would mean eliminating the anthropogenic introduction of NIS to the Baltic Sea. Table 2 shows the projected reductions in the introduction of NIS to the Baltic Sea in 2016-2030, taking into consideration the effects of existing measures and changes in the extent of human activities. The projected reduction is moderate, with some uncertainty of its magnitude. Achieving the HELCOM GES threshold with the existing measures does not seem likely based on the results of the analysis. For the latest HOLAS assessment period (2011-2016), 12 new primary introductions of NIS/CS were identified from the AquaNIS database, indicating a not good status (HELCOM 2018).

The impact of future development in the extent of human activities to the introduction of NIS is relatively important. The extent of both shipping and aquaculture (marine and inland) is expected to increase by 20% by 2030 in the most likely scenario, although the estimate for aquaculture is rather uncertain. This means that the projected pressure reduction results from the combined effect of existing measures and changes in the extent of human activities. However, activities and sources outside the Baltic Sea region contributing to the introduction of NIS are assumed to remain constant, as no development scenarios were made for these activities in the SOM analysis.

The most significant factor affecting the projected reduction in anthropogenic introductions of NIS from existing measures in the Baltic Sea is the entry into force of the Ballast Water Management Convention on 8 September 2017, through which requirements for managing ships' ballast water are currently being phased in for all ships in international trade.

Further details on the effectiveness of different measure types and activity-pressure input contributions can be found in Tables 4 and 5.

**Table 2.** Projected reductions (%) in the anthropogenic introduction of NIS from existing measures in the Baltic Sea in 2016-2030. The table depicts the most likely/expected total pressure input reduction, and standard deviation is given in parenthesis.

| **Pressure input**<br><br>**Area** | **Anthropogenic introduction of NIS** |
|---|---|
| Baltic Sea | 20<br>(11) ○●● |

Colour scale for the pressure input reductions in percent (based on the expected value):
<0%, 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the pressure input reductions (based on the relative size of the standard deviation to the expected value): low: ○○●, moderate: ○●●, high: ●●●
Data used: activity-pressure input contributions, effectiveness of measure types, information on existing measures, development of human activities

## What are the state components most affected by the effects of non-indigenous species?

The data from the pressure-state expert surveys for hazardous substances, benthic habitats, birds, fish, and mammals allow for identifying the state components most affected by the introduction of NIS. These five expert surveys provide expert views on the significance of various pressures to the state components in the SOM analysis. The most affected state components are identified based on the percent contribution of different pressures to the state component. First, the average percent significance of pressures has been calculated by state component, and then the pressures having the highest averages have been identified. This approach will overemphasize pressures important to geographically smaller assessment areas and may impact the rankings, as no corrections to account for the sizes of the assessment areas have been applied.

Table 3 shows the state components most affected by the effects of NIS. The most affected state components are bird species, flounder and one of the benthic habitat types.

Note that the introduction and effects of NIS have not been quantitatively linked in the SOM analysis, and thus results on how the effects of NIS change as a result of changes in their introductions are not available. Additionally, the SOM assessment for NIS only covers aquatic species. However, in the pressure-state surveys, the pressure *Effects of non-indigenous species* covers all NIS (both terrestrial and aquatic). Therefore, state components listed in Table 3 may be affected by species outside the scope of the SOM assessment for NIS, such as is the case of sandwich tern and common eider.

**Table 3. Top five state components most affected by the effects of non-indigenous species.** Listing is based on Baltic-wide averages of the significance of pressures to state components presented in each respective topic report. Average number of expert responses for the state component is given in parenthesis (total response count for the state component divided by the number of geographic areas for the state component).

| Pressure | 1st most affected state component | 2nd most affected state component | 3rd most affected state component | 4th most affected state component | 5th most affected state component |
|---|---|---|---|---|---|
| Effects of non-indigenous species | Sandwich tern (4.0) | Common eider (10.0) | Flounder (4.3) | Hard substrate epifauna dominated community (5.3) | |

Data used: expert responses on significance of pressures to state components
Less than five most affected state components are presented in cases where there is insufficient data for some state component(s) affected by the pressure, i.e. there are not enough expert responses to the significance of pressures to the state component in the survey (e.g. some mammals species). This corresponds to the criteria for the format of presentation.

## How effective are measure types in reducing pressure inputs?

This section presents the percent effectiveness of measure types in reducing *anthropogenic introduction of NIS* from a specific activity. The estimates are presented per activity, i.e. they portray the percent reduction in the pressure input from the activity in question, and not in the total input across all activities. Information on the reductions over all activities contributing to the pressure input is given in the section on the impacts of measure types. Data on the effectiveness of measure types originate from expert surveys and are at the Baltic Sea scale.

In the following, percent effectiveness is presented per activity, pressure, and measure type, and pooled over experts. The effectiveness estimates can be compared across measure types to assess, on average, how effective they are in relation to each other in reducing the pressure from the specific activities, or across activities to assess which measure type could be the most effective for each activity.

Table 4 presents the expected percent effectiveness and its standard deviation. Confidence depicts the most common rating of expert's confidence in their own responses to the effectiveness of measure types question. Annex 10 presents the distributions of the effectiveness of measure types in controlling the introduction of NIS for additional information.

The measure types for the *anthropogenic introduction of NIS* target four different activities, and each measure type can only reduce the pressure from a single activity. Most of the measure types are considered effective in reducing the introduction of NIS from the specific activity, with an effectiveness of over 50%. However, the uncertainty of these estimates is high as indicated by the large standard deviations. Thus, the effectiveness of most measure types is assessed to be approximately the same magnitude. Some measure types affecting shipping infrastructure (infrastructure such as canals) are considered to have lower effectiveness. Expert's confidence in their assessment is on average moderate.

Estimates of the effectiveness of measure types are used to assess the effects of existing measures in reducing the introductions of NIS to the Baltic Sea and calculate the reductions from existing measures by 2030.

It is important to note that measure types 82, 83, and 84 have been implemented in the SOM analysis as alternative implementations of the same measure (Ballast Water Management Convention (BWMC); Table 4) and only one measure type can be applied at one time. However, the approach of applying only one of these measure types at a time has been questioned and these measure types can be improved for future analyses (see section Reflection on measure types).

Although many effective measures exist, estimated pressure reduction remains low due to several factors. First, very few measures are being implemented in the Baltic Sea other than the BWMC. Other measures are under development or are locally implemented, but global, regional, or national efforts are limited to the management of ballast water and aquaculture. Second, based on the estimates in Table 4, even the most effective measure types, such as the BWMC, could not eliminate the risk of NIS introduction. Third, in the SOM analysis no measure types reduce the input from *activities and sources outside the Baltic Sea region*. This is perhaps a poor assumption, as the BWMC surely has an impact outside the Baltic Sea. This is further discussed in the section Reflection on measure types.

**Table 4. Effectiveness of measure types (%) in reducing the *anthropogenic introduction of NIS*.** The effectiveness of a measure type is the percent reduction in the pressure resulting from a specific activity. The table depicts the most likely/expected effectiveness, and standard deviation is given in parenthesis.

| Measure type ID | Activity<br><br>**Measure type** | Aquaculture | Transport – shipping ballast water | Transport – shipping biofouling | Transport – shipping infrastructure (canals) | Has corresponding existing measures in the SOM analysis (Yes/No) | Notes |
|---|---|---|---|---|---|---|---|
| 82 | Full implementation of the Ballast Water Management Convention | Not assessed | 70 (23) ○●● | Not assessed | Not assessed | Yes | Alternative implementations of the same measure – Only one can be implemented |
| 83 | Strict enforcement of compliance with the Ballast Water Management Convention through increased frequency of sampling and analysis of ballast water as part of port State control inspections | Not assessed | 66 (28) ○●● | Not assessed | Not assessed | No | |
| 84 | More stringent technical requirements and standards for ballast water and sediment management on ships | Not assessed | 64 (25) ○●● | Not assessed | Not assessed | No | |
| 85 | Enforce installation and maintenance of anti-fouling systems | Not assessed | Not assessed | 62 (20) ○●● | Not assessed | No | |
| 86 | Regionally harmonized in-water cleaning regulations | Not assessed | Not assessed | 63 (22) ○●● | Not assessed | No | |
| 87 | Adoption and implementation of a HELCOM Roadmap on Biofouling Management | Not assessed | Not assessed | 52 (24) ○●● | Not assessed | No | |
| 88 | Perform in-water inspections of ships' hulls for ships arriving from high risk areas prior to entering the Baltic. Take necessary action if NIS are identified (denying port access, requiring in-water cleaning of hull, dry-docking etc.) | Not assessed | Not assessed | 53 (16) ●●● | Not assessed | No | |
| 89 | Require hull niche areas to be free of biofouling | Not assessed | Not assessed | 51 (18) ○●● | Not assessed | No | |
| 90 | Implementation of biofouling management plan and biofouling management record book for ships | Not assessed | Not assessed | 51 (14) ●●● | Not assessed | No | |
| 91 | Risk assessment based in-water cleaning procedures | Not assessed | Not assessed | 61 (18) ○●● | Not assessed | No | |
| 92 | Mandatory hull cleaning en route | Not assessed | Not assessed | Not assessed | 55 (15) ●●● | No | |
| 93 | Mandatory ballast water treatment en route (canals) | Not assessed | Not assessed | Not assessed | 51 (18) ○●● | No | |

| Measure type ID | Activity<br><br>Measure type | Aquaculture | Transport – shipping ballast water | Transport – shipping biofouling | Transport – shipping infrastructure (canals) | Has corresponding existing measures in the SOM analysis (Yes/No) | Notes |
|---|---|---|---|---|---|---|---|
| 94 | Acoustic deterrents | Not assessed | Not assessed | Not assessed | 27<br>(16) ○●● | No | |
| 95 | Salinity barriers | Not assessed | Not assessed | Not assessed | 36<br>(20) ○●● | No | |
| 96 | Electrified barriers | Not assessed | Not assessed | Not assessed | 29<br>(20) ○○● | No | |
| 97 | Lock and dam operation optimized to minimize upstream-downstream mixing | Not assessed | Not assessed | Not assessed | 33<br>(16) ○●● | No | |
| 98 | Tighten restrictions for aquaculture management (transportation between facilities/prevent escapes etc) | 47<br>(18) ○●● | Not assessed | Not assessed | Not assessed | Yes | |
| 99 | Mandatory and rigorous NIS risk assessments prior to introduction of new fish stock (e.g. stock escape, parasites, etc) | 51<br>(17) ○●● | Not assessed | Not assessed | Not assessed | No | |
| 100 | Require rigorous invasion risk assessment before any potential NIS is allowed for importation | 58<br>(15) ●●● | Not assessed | Not assessed | Not assessed | No | |
| | Confidence | Moderate | Moderate | Moderate | Moderate | | |
| | Number of experts | 12-13 | 9-12 | 8-12 | 10-12 | | |

Colour scale for the effectiveness of a measure type in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the effectiveness estimate (based on the relative size of the standard deviation to the expected value): low: ○○●, moderate: ○●●, high: ●●●
Data used: expert responses on the effectiveness of measure types

## Which activities contribute to pressure inputs?

Table 5 shows the contribution of activities to the *anthropogenic introduction of non-indigenous species*. A data-based approach was used to estimate the activity-pressure linkages, and data have been gathered from the AquaNIS database on reported vectors of introduction for all primary introductions into the Baltic Sea in 2005-2016. Where multiple potential pathways were indicated in the database, the introduction was divided equally between each activity.

All the listed activities refer only to direct introductions (i.e. direct contributions to pressure) into the Baltic Sea. All indirect pressure contributions (secondary spread), defined here as anthropogenic introductions occurring outside the Baltic Sea which enable a NIS to enter the Baltic Sea via natural secondary spread following an anthropogenic introduction elsewhere (i.e. outside of the Baltic Sea), regardless of activity, are included under the category *activities and sources outside the Baltic Sea Region.* An additional category, *other/not determined*, captures remaining inputs not linked to a specific activity. Notable sources of NIS in this category include aquarium and live food trade escapes/releases

Altogether five different activities are identified to contribute to the *anthropogenic introduction of NIS*. The majority of the pressure contribution originates from *transport – shipping ballast* water, *activities and sources outside the Baltic Sea Region* and *transport – shipping biofouling*. The other two activities, namely *aquaculture*, and *transport – shipping infrastructure (canals),* have minor contributions to the pressure. The certainty of the estimates is high based on the standard deviations.

The contribution from biofouling is lower than expected based on historic introductions both globally (43-55%) and in the Baltic Sea (approximately 30-35%) (Hewitt and Campbell, 2010). However, this estimate covers all identified historic introductions, rather than the period 2005-2016 that was used in this analysis. Additionally, the methods used to calculate these values (e.g. sharing contributions across all potential vectors and the inclusion of the activity *activities and sources outside the Baltic Sea Region* are context-specific in that other analyses may prioritize the vector responsible for the primary introduction (or notable secondary spread) regardless of the geographic location or political boundaries. The focus of this analysis has been on measures the HELCOM Contracting Parties can implement in the Baltic Sea to reach the agreed environmental target, which has led to the perspective used in the SOM analysis.

**Table 5. Activity-pressure contributions (%).** The activity-pressure contributions show the percentage share the activity contributes to the pressure input (*anthropogenic input of NIS*). The table depicts the most likely/expected contribution (%), and standard deviations are given in parenthesis.

| **Anthropogenic introduction of NIS** | **Aquaculture** | **Activities and sources outside the Baltic Sea Region** | **Transport – shipping ballast water** | **Transport – shipping biofouling** | **Transport – shipping infrastructure (canals)** | **Other/not determined** |
|---|---|---|---|---|---|---|
| Whole Baltic Sea | 6<br>(2) ●●● | 29<br>(4) ●●● | 38<br>(4) ●●● | 17<br>(4) ●●● | 6<br>(3) ○●● | 4<br>(2) ○●● |

Colour scale for the contribution of the activity to the pressure input in percent (based on the expected value): 0-10%, 10-20%, 20-40%, 40-60%, 60-100%
Categories for the certainty of the activity-pressure input contribution estimate (based on the relative size of the standard deviation to the expected value): low: ○○●, moderate: ○●●, high: ●●●
Data used: entries on primary introductions into the Baltic Sea from the AquaNIS database for 2005-2016

## What are the impacts of measure types?

The impacts of measure types show the impact of measure types on reducing the anthropogenic introduction of NIS to the Baltic Sea. They include the effectiveness of measure types and the contribution of activities to the introductions. Thus, the impact shows how much the measure type reduces the pressure input across all activities contributing to the pressure input and gives indications on which measures could be the most relevant in addressing the anthropogenic introductions of NIS.

Three measure types appear as the most impactful: full implementation of the BWMC; strict enforcement of compliance with the BWMC through increased frequency of sampling and analysis of ballast water as part of Port State control inspections; and more stringent technical requirements and standards for ballast water and sediment management on ships. However, not all of these measures can necessarily be implemented simultaneously as they are to some extent alternative implementations of the BWMC, or hypothetical measures going beyond the BWMC.

Further effort on controlling NIS might be best targeted toward 1) globally or regionally coordinated actions to control introductions throughout the North Atlantic and Baltic Sea, and 2) efforts to control biofouling. However, due to the ambitious target of no new introductions within a 6-year assessment period, improvement of NIS control is required across all sectors. Ongoing work on the HELCOM framework of the drafting of the Proposed Regional Baltic Biofouling Management Roadmap is attempting to address both of these points and, if adopted, would be expected to lead to a decrease of new introduction of NIS via biofouling both from commercial shipping and recreational boating. Detailed information on the impacts of measures are given in Annex 11.

## What are the impacts of existing measures?

This section presents information about existing measures affecting activities and pressures for introductions of non-indigenous species. In the SOM analysis, existing measures are those measures in current policy frameworks (e.g. BSAP, EU MSFD, EU WFD, EU Biodiversity Strategy 2020) that affect pressures and environmental state within the time frame of the analysis (2016–2030). This includes measures that have been implemented, are partially implemented, or are planned to be implemented by 2030. Measures which have already been fully implemented and have fully affected pressures and environmental state by 2016 have been excluded, as no further improvement of status is expected during 2016–2030. Information about existing measures was compiled through a literature review and from Contracting Parties.

The impact is the percent reduction in a specific pressure from implementing the measure in the relevant spatial area. It has been calculated based on the effectiveness of the measure, proxied by the effectiveness of the measure type it corresponds to, and the contribution of activities to the pressure in question. Similar to the impact of a measure type, the impact of an existing measure indicates how much the measure reduces the pressure across all activities contributing to the pressure.

Table 6 presents the impacts of existing measures for anthropogenic introduction of NIS. They are presented both for the Baltic Sea scale and for the area affected by the existing measure. In addition, information on the share of the Baltic Sea area affected by the existing measure is included. Both the effectiveness of the measure and the spatial area affected are relevant for the impact at the Baltic Sea scale. Some existing measures may have high impact in the affected area, but their impact at the Baltic Sea scale is low because they only affect a small area, while some measures may have a relatively low impact in the affected area but affect a large share of the Baltic Sea.

There are three existing measures affecting the introduction of NIS in the SOM analysis. At the Baltic Sea scale, the main measure is the IMO Ballast Water Management Convention, which applies to almost the entire Baltic Sea. In addition, there are two aquaculture-related measures that have minor impacts locally, but their influence at the Baltic Sea scale is very limited.

**Table 6. Impacts of existing measures in reducing anthropogenic introduction of non-indigenous species.** Impact is the percent reduction in a specific pressure from implementing the measure. Measure name and description correspond to those used in Annex 4 for referencing purposes. In rare cases, the name and description may not be representative of the existing measure due to the free text reporting format used during existing measures data collection. Standard deviations are given in parenthesis. Note that values less than 0.5 have been rounded to zero.

| **Measure name** | **Description** | **Countries** | **Measure type** | **Activities** | **Impact at the Baltic Sea scale (%)** | **Impact in the area affected (%)** | **Affected area of the total Baltic Sea (%)** |
|---|---|---|---|---|---|---|---|
| IMO Ballast Water Management Convention | IMO Ballast Water Management Convention | All countries | Full implementation of the Ballast Water Management Convention | Transport – shipping ballast water | 26 (9) | 26 (9) | 100 |
| Aquaculture NIS | Article 4 Measures for avoiding adverse effects<br>1. Member States shall ensure that all appropriate measures are taken to avoid adverse effects to biodiversity, and especially to species, habitats and ecosystem functions which may be expected to arise from the introduction or translocation of aquatic organisms and non-target species in aquaculture and from the spreading of these species into the wild.<br>2. The competent authorities in the Member States shall monitor and supervise aquaculture activities so as to ensure that:<br>(a) closed aquaculture facilities comply with the requirements laid down in Article 3(3); and<br>(b) transport from or to closed aquaculture facilities takes place in conditions that are such as to prevent the escape of alien or non-target species. | DK | Tighten restrictions for aquaculture management (transportation between facilities/prevent escapes etc) | Aquaculture | 0 (0) | 3 (1) | 11 |
| Denmark - Aquaculture Manual | Mariculturists prevent the release of NIS from their activities (aquaculture). The revised Aquaculture Manual will describe the conditions that should be monitored by the authorities in relation to aquaculture operations, as well as those that should be monitored during transportation of fish between port and aquaculture areas. The Manual also includes the notification of authorities and follow-up/limitation of releases. | DK | Tighten restrictions for aquaculture management (transportation between facilities/prevent escapes etc) | Aquaculture | 0 (0) | 3 (1) | 11 |

## Background of respondents

For non-indigenous species, an expert survey was conducted to assess the effectiveness of measure types. Altogether 13 survey responses with 15 contributing experts were received. One of the answers was a group response, with three contributing experts. The number of experts contributing to the NIS effectiveness of measures survey by country is shown in Table 6.

**Table 6. Number of experts contributing to the NIS survey**

| Survey | DE | DK | EE | FI | LT | LV | PL | RU | SE | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| Effectiveness of measures | 4 | 2 | 1 | 2 | - | 2 | 1 | - | 3 | 15 |

The experts participating in the effectiveness of measures survey had very diverse backgrounds, covering fields such as marine biology, monitoring, law, NIS, pollution prevention, and aquatic science. One third of the experts had either 5-10 years or 10-20 years of experience (each), while 13% had over 20 years or 3-5 years of experience (each) (Table 7). Experts represented research institutions, state agencies, ministries, and environmental institutions.

**Table 7. Years of experience in the field for the NIS surveys**

| | **Effectiveness of measures** | |
|---|---|---|
| **Years** | **Number of experts** | **Share of experts** |
| 0-2 years | 1 | 7 % |
| 3-5 years | 2 | 13 % |
| 5-10 years | 5 | 33 % |
| 10-20 years | 5 | 33 % |
| over 20 years | 2 | 13 % |

# Discussion

## Impact of alternative scenarios for development of human activities

The detailed results are presented for the most likely development scenario for the extent of human activities in 2016–2030. In addition, three other development scenarios were estimated: no change, low change, and high change scenarios. These scenarios cover 9 out of the 31 activities in the SOM analysis. The extent of other activities is assumed to remain constant in all scenarios.

As activities contribute to pressure inputs, their assumed change over time affects the pressure input reductions and probability to achieve GES or state improvements. The impact depends on to what extent the activities contributing to the specific pressure input are covered in the change scenarios. For NIS, the coverage of activities that contribute to pressure inputs in the change scenarios is rather high.

The impact of alternative development scenarios is relatively important for NIS. Compared to the default version results using the most likely development scenario, assuming no or low change in human activities increases the projected reductions in the anthropogenic introduction of NIS, and assuming a high change decreases them. The projected reductions are approximately 27% in the no change scenario (up from 20% in the default scenario). This difference stems mainly from changes in the extent of shipping and additionally from marine and inland aquaculture in the different scenarios. Thus, the assumed development of human activities influences the projected pressure reductions, but this does not change the main results on the sufficiency of measures to achieve GES of no new introductions, which is that is predicted to not be achieved by 2030.

## Impact of using literature data on effectiveness of measures

In addition to survey data from experts, literature data on the effectiveness of measures has been compiled. The literature data points have been used in a similar way as the expert survey responses, and when it has been available, it has been used to replace the expert estimates of the effectiveness of the measure type. However, literature estimates are not available for all measure types. Thus, it is not possible to implement the model estimation and provide the results relying entirely on the literature data on effectiveness of measure types. Thus, the model including the literature estimates is a combination of literature and expert data on effectiveness of measure types. The origin of other data components is not affected.

For NIS, 15 estimates from 6 studies could be included in the SOM model. The projected reduction in the anthropogenic introduction of NIS is not affected by the inclusion of literature data as the data is only for hypothetical measure types that do not have any corresponding existing measures in the Baltic Sea.

## Evaluation of quality and confidence

The SOM analysis for NIS has been able to evaluate the sufficiency of existing measures to achieve the GES threshold of no new introductions. All elements of the results have been presented in a quantitative format, as the data have been deemed to suffice for that. However, the analysis has not included a link between the introduction and effects of NIS, and thus the SOM assessment has not been able to provide results on how the effects of NIS might change, and SOM results for the other topics which may be affected by NIS do not take into account the reduction in the anthropogenic introduction of NIS estimated in this report.

The overall certainty of the assessment for NIS could be characterized as moderate. The number of expert responses to the effectiveness of measures survey is relatively high, and experts from seven coastal countries have contributed to the assessment. In addition, the activity-pressure contributions are from the AquaNIS database. For the individual results, average certainty is high for the activity-pressure contributions, moderate for the effectiveness of measures types, and moderate for projected reductions in the introduction of NIS. The most common confidence level experts reported for their own evaluations is moderate for effectiveness of measures. Particularly the estimates for the effectiveness of measures are rather uncertain.

There were some technical challenges that affected the survey implementation. Firstly, there was a problem in the survey software for the effectiveness of measure types survey that resulted in losing some responses. The original responses became often unusable, as it was not possible to identify which items had been omitted on purpose and which were lost data. This issue was addressed by sending follow-up invitations for experts to review and, when needed, complement their original saved response. Not all experts participated in the review and those responses had to be deleted from the final sample, thus the final numbers presented above represent only those with completed and reviewed responses. Secondly, the simultaneous assessment of effectiveness of a measure type and certainty of that effectiveness proved in some cases difficult, as it required placing non-quantitative markers in a coordinate system to generate quantitative estimates. The markers were translated into effectiveness and certainty values between 0 and 100. Some experts would have preferred that the quantitative estimates would have been visible and could have been transparently influenced.

When interpreting the results, the assumptions and generalizations that were made when collecting the input data and defining and using the data on activity-pressure input contributions, measure type effectiveness and pressure-state linkages need to be taken into account. The input data are based mainly on expert elicitations rather than existing models and data and reflect substantial uncertainty. For more information on the SOM methodology, data collection and assumptions, see this document.

The concerns regarding the proportion of introductions occurring through biofouling should be kept in mind when using the results presented in this report. The SOM analysis on NIS holds a context-specific perspective that may not be best suited to considering issues of a global scale. This is further complicated by the stochastic and spreading nature of NIS introductions. However, these concerns do not preclude the use of the SOM results and it is clear that significant effort is still required across all sectors to reach the target of no new introductions.

## Reflection on measure types

The SOM assessment on NIS has a clear gap in the measure types concerning *activities and sources outside the Baltic Sea region*. The BWMC should have been surveyed concerning its impact on this activity. Alternatively, assumptions could have been made regarding the proportion of NIS introductions in the North-East Atlantic and the effectiveness estimates for the BWMC in the Baltic Sea could have been applied to the North-East Atlantic. As a result, the projected pressure reduction for *anthropogenic introduction of NIS* is likely underestimated do to the current focus being only on direct new introductions. Regardless, future analyses can be improved through better measure type coverage of this activity.

The description of measure types 82, 83, and 84 (all relating to the BWMC) have not made the relationships between these measures clear to topic experts. The methodology and implementation of structural overlaps between measure types (see methodology document) was handled after the measure types were already implemented and this weakness was not recognized before both components were in place. Improvement on this issue should be easily achieved in any future work.

During the review of the SOM results, feedback was received concerning the construction of the measure types for NIS, particularly concerning biofouling measures. While there do not appear to be any invalidating flaws in the measure types used, there clearly remains room for improvement. In future iterations of the SOM analysis, review of the measure types for each topic should be standard practice with a focus on diverse perspectives and expertise.

It is to be noted that while some of the measure types are likely to be implemented in the coming years, others are of a more hypothetical nature and not based on the existing regulatory framework. The intention in this respect was to cover as many plausible measure types as possible. As for all topics, the generality of the measure types is a concern and a balance between specificity and pan-regional relevance should be a top priority during any future redesign of the measure types.

## Lessons learned

Given the importance of global and large regional measures to manage the introduction of NIS, the hard cut-off made between the Baltic Sea and the rest of the world in the activity-pressure contributions methodology should be reviewed as a first step, before being implemented further. While generally outside the framework of the SOM analysis, additional effort on this point could allow for more accurate assessments of the impact of global measures (e.g. BWMC) and possibly regional measures, by allowing the measures to impact non-Baltic Sea activities. The implications of this expansion on time lags and the level of detail in species' invasion histories required to complete such an expansion would need further consideration before this could be implemented, to ensure achievable model design and data availability go hand in hand.

## Use of results, implications, and future perspectives

The successful introduction of NIS into new areas depends on a number of factors, such as characteristics and tolerances of the species, characteristics of the vector, number and frequency of specimen being introduced, and abiotic and biotic conditions in the recipient area. Also, the effects on the environment of an introduced NIS are typically not know until long after establishment, and they are not possible to predict reliably beforehand, even based on data from other areas where the same NIS has established viable populations. An introduction of a specific NIS can have devastating effects on the environment and the economy in one region, while they may be negligible in another. Due to these uncertainties and the fact that the probability or effects of NIS introductions cannot currently be quantified, the SOM analysis had to be largely based on expert input, and as such, the results would have benefited from a larger pool of experts contributing to the work. Nevertheless, the results give a good indication on the most important measure types that would need to be implemented in order to reach GES and clearly indicate that not enough is being done to control NIS introductions.

Much of the effort in controlling NIS is either ongoing (i.e. BWMC) or under development (e.g. Proposed Regional Baltic Biofouling Management Roadmap). This increases the uncertainty of the SOM analysis. In the future, more will be known on the implications of the implementation of the BWMC thus more will be known on its gaps and need for additional measures to be implemented. The same applies for the non-mandatory IMO *Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species* (Resolution MEPC.207(62)) (IMO Biofouling Guidelines); or in the case of leisure boats less than 24 meters in length, *Guidance for minimizing the transfer of invasive aquatic species as biofouling (hull fouling) for recreational craft* (MEPC.1/Circ.792) (IMO Biofouling Guidance), both of which are currently under review. Moreover, at regional level, the impact of the Proposed Regional Baltic Biofouling Management Roadmap would need to be considered if and when it is adopted. Future analyses can benefit from more empirical studies of the impact of such measures.

It should be noted that no quantitative link exists between introductions of NIS and their effects in the SOM model. Even with significant assumptions such a link may not be possible to include in the assessment, given biases in NIS monitoring and research toward high impact or high visibility species and the difficulty of applying a single standard of impact of NIS. Future research and global coordination may change these circumstances, in particular ongoing work with a food web focus for example, but currently the SOM analysis cannot take the effects of NIS on other state components into account in the analysis.

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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

# Annexes

Annexes 1–9 contain the expert surveys as well as information on the measure types and the literature review. They are available on the SOM Platform workspace.

Annexes 10–11 contain graphs and tables that provide additional information and perspectives on the results.

## Annex 1 Activity-pressure input survey template

Excel used as a template for receiving data for the activity-pressure input survey.

## Annex 2 Modified activity list (if modified)

Excel containing the modified activity list.

## Annex 3 Measure types list

PDF containing the measure types used in the assessment of the effectiveness of measures for *Non-indigenous species*. Document includes examples of existing measures that if implemented would be included in the corresponding measure type.

## Annex 4 Linking existing measures to measure types

Excel containing the identified existing measures and their relationship to the measure types used in the SOM analysis.

## Annex 5 Literature review search terms

Excel containing the search terms used during the literature review on effectiveness of measures for *Non-indigenous species*.

## Annex 6 Literature review summary

Excel document containing the effectiveness of measures data retrieved from the literature review.

## Annex 7 Topic structure

Excel containing the relationships between measure types, activities, pressure inputs, state components, and sub-basins. Also contains information on GES thresholds.

## Annex 8 Effectiveness of measures survey

PDF of the Effectiveness of measures survey for *Non-indigenous species*.

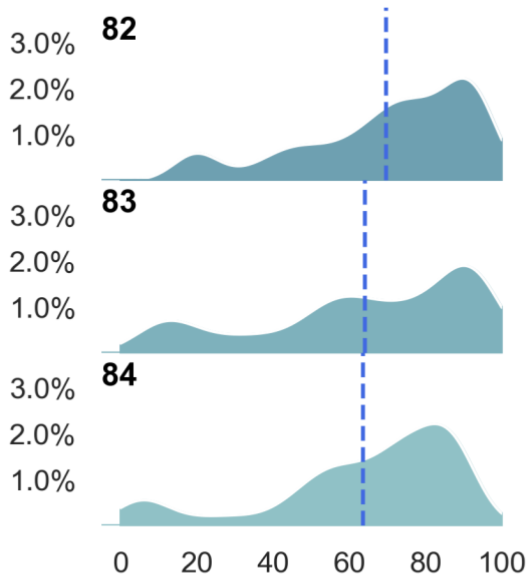
## Annex 9 Pressure-state survey

The SOM analysis for *Non-indigenous species* does not include an analysis to state, so no pressure-state survey is available.

## Annex 10 Supplementary results for effectiveness of measures

**Table A1. Distribution of the effectiveness of measure types in reducing anthropogenic introduction of NIS.** The effectiveness of a measure type is the percent reduction in a pressure resulting from a specific activity. The graphs present the probability distribution of effectiveness, based on expert responses or literature estimates. The dashed line represents the expected value. Figures showing only a dashed line and no apparent probability distribution are point estimates without variation.

| | |
|---|---|
| **Pressure:** | Anthropogenic introduction of NIS |
| **Activity:** | Transport – shipping ballast water |
| **Measure type:** | 82: Full implementation of the Ballast Water Management Convention |
| | 84: More stringent technical requirements and standards for ballast water and sediment management on ships |
| | 83: Strict enforcement of compliance with the Ballast Water Management Convention through increased frequency of sampling and analysis of ballast water as part of port State control inspections |
| **Expert assessment:** | 9-12 experts, confidence = moderate |



**Pressure:** Anthropogenic introduction of NIS

**Activity:** Transport – shipping biofouling

**Measure type:** 91: Risk assessment based in-water cleaning procedures

86: Regionally harmonized in-water cleaning regulations

85: Enforce installation and maintenance of anti-fouling systems

87: Adoption and implementation of a HELCOM Roadmap on Biofouling Management

88: Perform in-water inspections of ships' hulls for ships arriving from high risk areas prior to entering the Baltic. Take necessary action if NIS are identified (denying port access, requiring in-water cleaning of hull, dry-docking etc.)

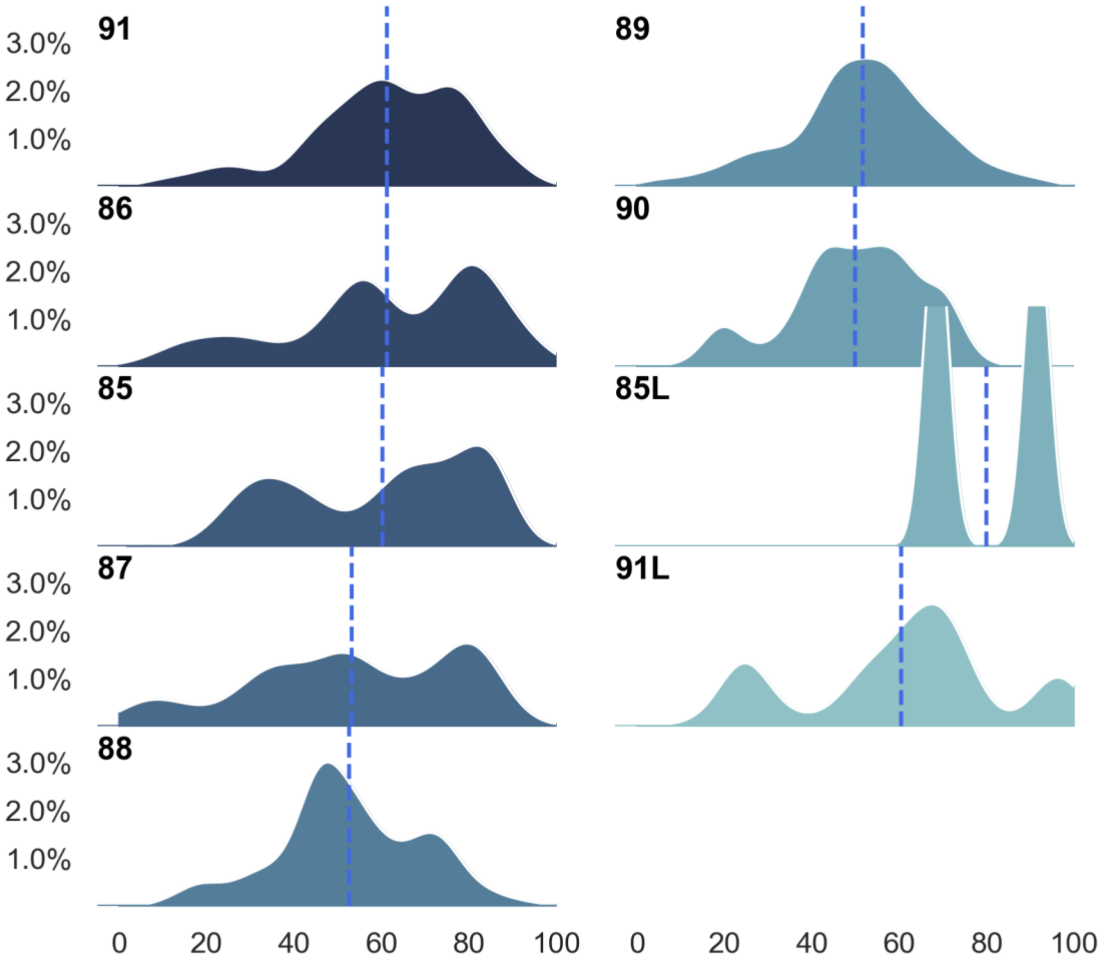
89: Require hull niche areas to be free of biofouling

90: Implementation of biofouling management plan and biofouling management record book for ships

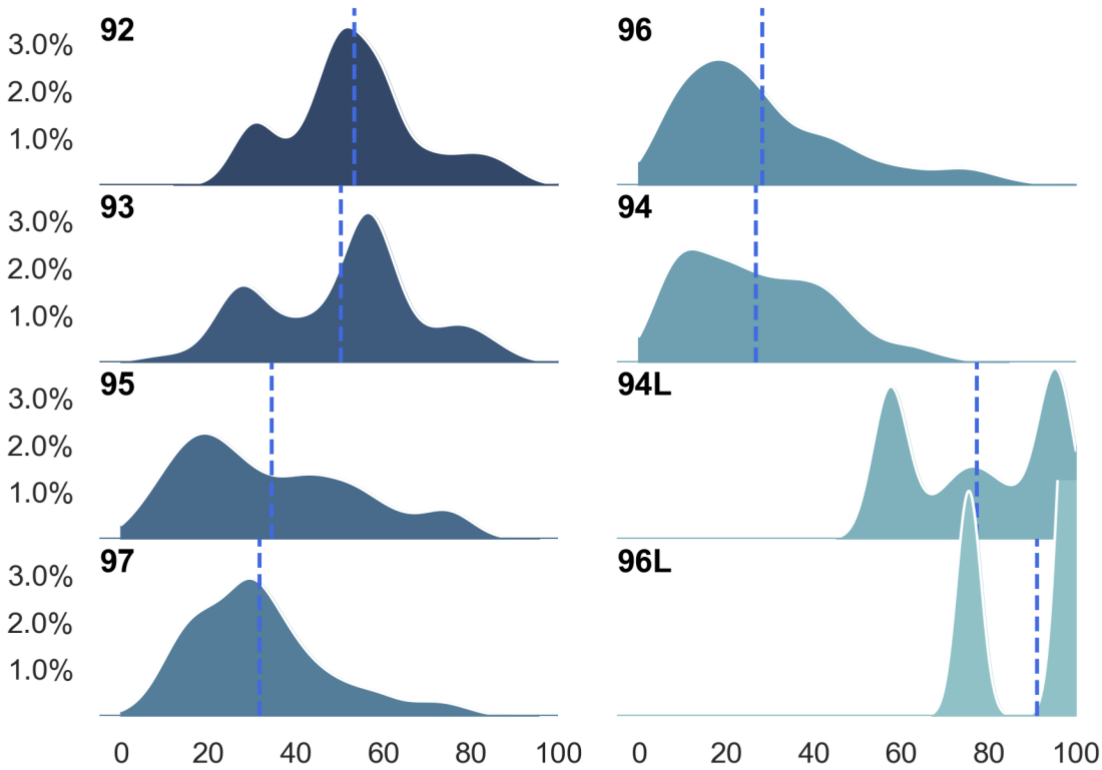
85L: Enforce installation and maintenance of anti-fouling systems (literature based)

91L: Risk assessment based in-water cleaning procedures (literature based)

**Expert assessment:** 8-12 experts, confidence = moderate



| | |
|---|---|
| **Pressure:** | Anthropogenic introduction of NIS |
| **Activity:** | Transport – shipping infrastructure (canals) |
| **Measure type:** | 92: Mandatory hull cleaning en route |
| | 93: Mandatory ballast water treatment en route |
| | 95: Salinity barriers |
| | 97: Lock and dam operation optimized to minimize upstream-downstream mixing |
| | 96: Electrified barriers |
| | 94: Acoustic deterrents 96: Electrified barriers |
| | 94L: Acoustic deterrents (literature based) |
| | 96L: Electrified barriers (literature based) |
| **Expert assessment:** | 10-12 experts, confidence = moderate |



**Pressure:** Anthropogenic introduction of NIS

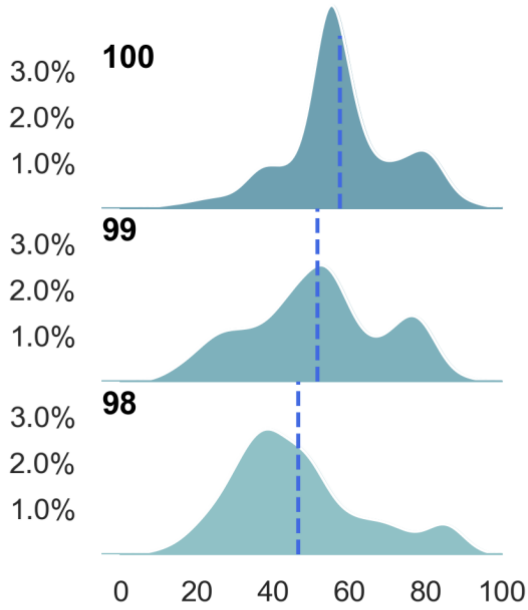
**Activity:** Aquaculture

**Measure type:** 100: Require rigorous invasion risk assessment before any potential NIS is allowed for importation

99: Mandatory and rigorous NIS risk assessments prior to introduction of new fish stock (e.g. stock escape, parasites, etc.)

98: Tighten restrictions for aquaculture management (transportation between facilities/prevent escapes etc.)

**Expert assessment:** 12-13 experts, confidence = moderate



## Annex 11 Impacts of measure types

**Table A2. Impacts of measure types (%) in reducing the anthropogenic introduction of non-indigenous species to the Baltic Sea.** The impact shows how much the measure type reduces the pressure input across all activities contributing to the pressure input.

| Measure type | Mean (Standard deviation) |
|---|---|
| Full implementation of the Ballast Water Management Convention | 26 (9) |
| Strict enforcement of compliance with the Ballast Water Management Convention through increased frequency of sampling and analysis of ballast water as part of port State control inspections | 25 (11) |
| More stringent technical requirements and standards for ballast water and sediment management on ships | 24 (10) |
| Regionally harmonized in-water cleaning regulations | 11 (5) |
| Enforce installation and maintenance of anti-fouling systems | 11 (4) |
| Risk assessment based in-water cleaning procedures | 10 (4) |
| Perform in-water inspections of ships' hulls for ships arriving from high risk areas prior to entering the Baltic. Take necessary action if NIS are identified (denying port access, requiring in water cleaning of hull, dry-docking etc.) | 9 (3) |
| Adoption and implementation of a HELCOM Roadmap on Biofouling Management | 9 (5) |
| Implementation of biofouling management plan and biofouling management record book for ships | 9 (3) |
| Require hull niche areas to be free of biofouling | 9 (4) |
| Require rigorous invasion risk assessment before any potential NIS is allowed for importation | 4 (1) |
| Mandatory hull cleaning en route | 3 (2) |
| Mandatory and rigorous NIS risk assessments prior to introduction of new fish stock (e.g. stock escape, parasites, etc) | 3 (1) |
| Mandatory ballast water treatment en route | 3 (2) |
| Tighten restrictions for aquaculture management (transportation between facilities/prevent escapes etc) | 3 (1) |
| Salinity barriers | 2 (2) |
| Lock and dam operation optimized to minimize upstream-downstream mixing | 2 (1) |
| Electrified barriers | 2 (2) |
| Acoustic deterrents | 2 (1) |