HELCOM Science Agenda

Baltic Marine Environment Protection Commission

Science & knowledge

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Glossary

BSAP	Baltic Sea Action Plan. A comprehensive regional programme of measures and actions to improve the state of the Baltic Sea. The first action plan was adopted in 2007 and the updated BSAP was adopted in October 2021.
BWMC	Ballast Water Management Convention
Contracting Parties	Refers to the signatories to the Helsinki Convention, i.e. the nine countries bordering the Baltic Sea and the EU.
EA	Ecosystem approach
GHG	Greenhouse gases
HELCOM	Helsinki Commission. Governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area," also known as the Helsinki Convention.
HELCOM Ministerial Declaration	Political declarations in which Contracting Parties commit to taking further action to protect the marine environment of the Baltic Sea.
HELCOM Nutrient reduction scheme	The HELCOM Nutrient Reduction Scheme is a regional approach to sharing the burden of nutrient reductions to achieve the goal of a Baltic Sea unaffected by eutrophication as agreed by the Baltic Sea countries.
HELCOM Recommendations	Adopted by the Helsinki Commission, HELCOM Recommendations focus on measures to address certain pollution sources or areas of concern. The Recommendations are to be implemented by the Contracting Parties through their national legislation.
IMO	International Maritime Organization
MARPOL	International Convention for the Prevention of Pollution from Ships
MPA	Marine protected area
MSFD	Marine Strategy Framework Directive of the European Union
MSP	Maritime spatial planning
NIS	Non-indigenous species
UN SDGs	United Nations Sustainable Development Goals

Background

About HELCOM

The Baltic Marine Environment Protection Commission – also known as the Helsinki Commission (HELCOM) – is an intergovernmental organization based on a regional sea convention for the Baltic Sea area. HELCOM consists of ten members: the nine Baltic Sea countries Denmark, Estonia, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden, and the European Union. A platform for environmental policy making at the regional level, HELCOM works for a healthy Baltic Sea.

The Helsinki Convention

The Helsinki Convention was signed in 1974 by the Baltic Sea coastal states to address the increasing environmental challenges that were having a severe impact on the region's marine environment. The Helsinki Convention contains an obligation to protect the Baltic Sea from all sources of pollution from land, air and sea. It also obliges the signatories to taking measures to conserve habitats and biological diversity and to ensuring the sustainable use of marine resources.

The Baltic Sea Action Plan

To help reach its environmental objectives, HELCOM adopted the Baltic Sea Action Plan (BSAP) in 2007. The BSAP is HELCOM's strategic programme of measure and actions to achieve a good status of the Baltic Sea's environment. The BSAP was updated in 2021, to adjust the current actions and to widen its scope with regard to issues such as climate change, marine litter, disturbance to the seabed and underwater noise.

The HELCOM Science Agenda

The HELCOM Science Agenda has been prepared to support the implementation of the BSAP and other HELCOM agreements. It highlights knowledge needs that must be met within the upcoming 10 years. The Science Agenda aims at communicating HELCOM science needs to funding agencies, to inform and inspire scientists to direct their interest towards closing the knowledge gaps required for HELCOM work, and to increase the interaction between science and policy.

Introduction

Rationale for a HELCOM Science Agenda

HELCOM has set ambitious goals, objectives and agreements to protect and improve the state of the Baltic Sea. The implementation of these commitments involves the application of recent science-based knowledge in wide areas of marine research and related topics. HELCOM commitments include, for example, the development of common targets for the reduction of pressures, joint guidelines for sustainable use of resources, the implementation of measures, analyses of economic and social aspects of marine management, and assessing the state of the environment. The preparation of syntheses of available knowledge is often needed to initiate the work and in some cases research projects are required to supply new knowledge for achieving an effective implementation.

This Science Agenda is foremost developed to highlight identified knowledge and science needs to realize existing HELCOM agreements and strategies, such as:

- The Baltic Sea Action Plan – the joint environmental policy programme of HELCOM countries for reaching good environmental status of the Baltic Sea, as updated in 2021 and to be implemented by 2030;
- HELCOM Recommendations – agreements on measures to address certain pollution sources or areas of concern in the Baltic Sea;
- Tasks assigned to HELCOM expert groups – including the development of common management guidelines, indicators, proposals for new measures;
- Regular assessments – evaluating the state of the Baltic Sea, identifying pressures from land-based and seabed sources, following-up of management measures.

While HELCOM work and decision-making processes are based on and guided by the best available science, HELCOM itself is not a scientific body and largely depends on advice from a wider scientific community. The main aim of the Science Agenda is therefore to communicate HELCOM science needs to external funding agencies, to inform and inspire scientists to direct their interest and apply for funds towards meeting the knowledge needs in HELCOM, and to increase the interaction between science and policy. The main target audience for the Science Agenda is thus the national authorities engaged in HELCOM work and marine policies in general, national and international science funding bodies, and the scientific community.

Formulating a HELCOM Science Agenda generates added value by concentrating research efforts towards bottle-neck knowledge gaps preventing the achievement of good environmental status in the Baltic Sea. Further, it should stimulate joint regional projects, thereby also increasing potential gains by sharing experience and knowledge transfer between countries. The HELCOM Science Agenda is also linked to the UN Decade of Ocean Science and the implementation of the Science Agenda can contribute to building the knowledge needed to reach the UN Sustainable Development Goals by 2030 (see Annex 2).

It is worth noting that the Science Agenda does not address data needs or monitoring programmes as such. These are two key activities of HELCOM work that are governed by the HELCOM 'Data and Information Strategy' and 'Monitoring and Assessment Strategy'. These Strategies are implemented through regular activities and updates of HELCOM monitoring programmes.

How the Science Agenda was developed

The first step in developing this Science Agenda was a request to HELCOM Expert Groups, networks and Working Groups to identify the knowledge and research needs that are necessary to implement HELCOM agreements in their respective areas of work. This survey generated nearly 200 contributions which, once collated and organised, formed the core of a comprehensive and detailed inventory of HELCOM knowledge and research needs. Throughout the process of developing the Science Agenda additional content was added. This inventory is provided as supplementary material to this report (Attachment 1) and will remain a living document where emerging needs may be added based on periodical review.

A Task Group with national representatives was established to prepare a consolidated Science Agenda using the survey results as a basis. The Task Group has drawn information from the survey contributions but also complemented them, including the identification of knowledge needs with a more overarching perspective directed towards the implementation of the ecosystem approach, a fundamental principle of HELCOM work. In 2024, following the finalization of the third Holistic Assessment of the Status of the Baltic Sea (HOLAS 3), review and targeted update of the Science Agenda was executed. The process targeted introducing prioritised knowledge needs identified through the extensive review processes of the HOLAS 3 results and products, as well as removing any of the knowledge and research needs identified in 2021 that were deemed to already have been addressed.

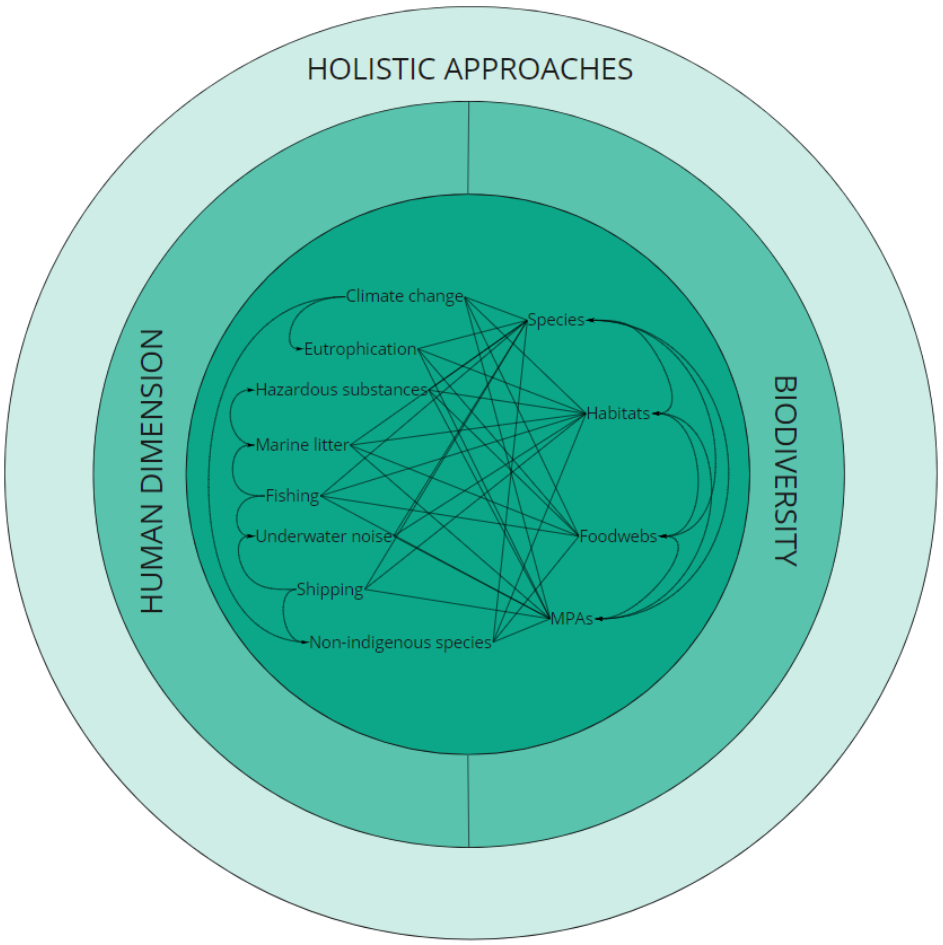


Figure 1. Conceptual overview of linkages across topics and chapters.

How to read the Science Agenda

Chapters 1-3 highlight principal HELCOM knowledge and research needs that must be met to support the implementation of the updated BSAP by 2030, as well as other HELCOM agreements, and is structured around priority topics for HELCOM work.

Chapter 1, which focuses on the theme of 'Biodiversity', presents the knowledge needed to better understand and develop methods to assess the status of and impacts on the Baltic Sea species and habitats and the development of measures that can improve their status.

Chapter 2 on the 'Human dimension' describes science needs related to human activities and the resulting pressures on the Baltic Sea ecosystem and the development of measures to reduce their impact.

Chapter 3 on 'Holistic approaches' addresses overarching approaches that can support the goal of reaching a good environmental status, such as the ecosystem approach.

While the Science Agenda is organized by topics, the outlined knowledge needs are interlinked and will all contribute to the implementation of the ecosystem approach in the Baltic Sea.

Finally, Chapter 4 includes a reflection on how the implementation of the Science Agenda can be realized.

The annexes provide associated information regarding the highlighted knowledge needs. They aim to specify in more detail the type of knowledge that is needed, the HELCOM agreements that will benefit from the knowledge, and how the new knowledge can contribute to the implementation of other ocean-related goals. Some of the identified knowledge needs can likely be met through short-term desktop studies and syntheses while others will require longer-term research projects.

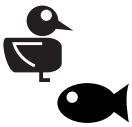
1. Biodiversity

The Baltic Sea is known for its unique biodiversity, featuring both freshwater and marine species that have adapted to the brackish environment, although the diversity in terms of number of species is relatively low compared to other sea areas. The prevalence of species and communities is largely governed by strong gradients in salinity from north-to-south, coastal-to-offshore, and surface-to-bottom in sub-basins where a halocline prevails. In addition, seasonal changes in temperature as well as temporary and permanent oxygen deficits influence the occurrence and composition of species. Benthic habitats and biotopes are also influenced by substrate composition, morphology, exposure, water exchange and depth. When combining these factors in the comparatively small geographic area of the Baltic Sea the result is a mosaic of varied biotopes exhibiting great diversity in function and structure. The Baltic Sea biodiversity is thus dynamic in time and variable in space. This also influences the management of human activities.

The species and communities provide many goods and services to the Baltic Sea countries such as food and plant-based resources, but they also regulate biological and chemical processes. Biodiversity in good status contributes to ecological resilience, i.e. the capacity of an ecosystem to respond to and recover from disturbances. The composition of species and communities also dictates the structure and function of food webs, another key component determining resilience. The genetic diversity furthermore caters for adaptation to more long-term changes in the environment, a capacity that may be essential considering the projected changes in climate in the Baltic Sea area.

Since the beginning of the 1900s the Baltic Sea has been impacted by a high and increasing number of pressures stemming from human activities, as indicated in chapter 2 of this report. Through the Helsinki Convention the Baltic Sea countries have agreed to take all necessary measures to protect the natural habitats, natural processes and biological diversity in the marine and coastal environment of the Baltic Sea area. The protection and mitigation of impacts on biodiversity is a key component of joint HELCOM work, including the common goal of having an ecologically coherent and well-managed network of marine protected areas in the Baltic Sea. However, the most recent HELCOM Red List assessments from 2013 indicate 145 species and 17 biotopes or biotope complexes as threatened (HELCOM 2013). The HELCOM State of the Baltic Sea Report from 2018 also shows that many species groups and communities are not in a good status (HELCOM 2018a).

This chapter focuses on knowledge needs that should be addressed to properly assess the status of the Baltic Sea biodiversity, to understand the effect of pressures on different biological components, and the development and evaluation of management measures that are required to protect and restore biodiversity and food webs. Measures to reduce pressure on the Baltic Sea ecosystem are primarily addressed in Chapter 2 on the 'Human dimension'.



1.1. Species

Species from across all flora and fauna in the Baltic Sea have been impacted by human-induced changes in the ecosystem. While the status has improved for several species as a result of well-targeted measures to alleviate these pressures, there are still many species threatened or even at risk of extinction (HELCOM 2013) or having unfavourable living conditions. Baltic Sea populations are disturbed by human activities both directly, e.g. through habitat deterioration via physical disturbance, and indirectly via contaminants and eutrophication, noise as well as the introduction of non-indigenous species. Bycatch in various types of fishing gear, hunting and fishing are main causes of human-induced mortality of marine animals. Awareness is also emerging of marine litter, including microplastics, as a pressure on most of the species, while relatively little is known about the impact on specific species and communities. Dedicated research efforts are needed to better understand the dynamics and distribution of the Baltic Sea species and communities, and the impact of human activities. This is needed both to ensure that human activities can be managed at sustainable levels and to establish effective protection and conservation measures for Baltic Sea species and species communities, ultimately securing good status of the environment.

The outlined knowledge needs are relevant for the implementation of numerous HELCOM recommendations[1] related to the protection of threatened species in general as well the specific protection of seals, harbour porpoises and birds.

Highlighted science needs

Species distribution

1.1.1 Better knowledge of species distribution, population sizes, ecology and habitat selection to support precise status assessments and establish how to best direct management measures.

1.1.2 A need for increased understanding of gene-flow and the interaction of the three populations of Ringed seals are needed, to improve assessments.

Indicators and impact of pressures

1.1.3 Development and optimization of methodology for the assessment of:

- water bird reproductive success, which accounts for various species groups and provides ecologically relevant information on status across groups;
- abundance and distribution of harbour porpoises throughout the full range of the species;
- health aspects that account for spatial and inherent variation between species for seals and harbour porpoises, inclusive of the impact of hazardous substances.

1.1.4 Research on the impact of impulsive and continuous underwater noise on marine mammals, fish populations and benthic communities; in particular, long-term consequences of masking, disturbance and hearing loss on survival and reproduction of marine mammals, and population-level consequences of impact at different life stages in species with pelagic larvae;

1.1.5 Research on the impact of macrolitter and microplastics on species and communities;

1.1.6 Evaluation of population level impacts of bycatch of all relevant species.

1.1.7 An improved understanding of marine mammals is needed, as they are at the top of the marine food web, which makes them sensitive to changes throughout the ecosystem, and changes in food webs on which they rely (and for which our current understanding is poor). This may be significant with potential changes in food availability and altered transfer of contaminants;

Conservation plans

1.1.8 Better knowledge for the development of effective species conservation plans, in particular for marine mammal, bird and fish populations;

1.1.9 Development of approaches to quantifying the effectiveness of specific conservation measures for species;

1.1.10 Research to define precautionary approach levels for seals in their management units.

1.1.11 Research to establish clear conservation objectives and quantifiable threshold values (such as Limit Reference Values and Target Reference Limits) for effective future evaluations and conservation efforts of species

1 For example Recommendation (Rec.) 17/2 Protection Of Harbour Porpoise In The Baltic Sea Area; Rec. 27/28-2 Conservation Of Seals In The Baltic Sea Area; Rec. 34e/1 Safeguarding Important Bird Habitats And Migration Routes In The Baltic Sea From Negative Effects Of Wind And Wave Energy Production At Sea; Rec. 37/2 Conservation Of Baltic Sea Species Categorized As Threatened According To The 2013 Helcom Red List.

1.2. Habitats

Marine habitats can largely be divided into water column (pelagic) and seabed (benthic) habitats. While these represent two seemingly very different features of the environment, they are closely interlinked, especially in the shallow Baltic Sea. Inadequate status of species and communities is closely related to changes in their physical habitats, since they need intact feeding, resting, reproduction and nursery areas. For benthic communities and biotopes anthropogenic pressures resulting in loss and disturbance to the seabed, as well as eutrophication, have a strong impact. For the pelagic habitats eutrophication, rising temperatures, potentially enhanced salinity stratification and concomitant higher primary production lead to plankton regime shifts. All this may lead to oxygen depletion in deeper areas. This in turn will cause changes in both pelagic and benthic biotopes and overall food web dynamics.

For the implementation of the BSAP and HELCOM Recommendations[2], improved knowledge about interactions between pressures, habitat structures and ecosystem functions is needed. In addition there is a need for further development of methods to restore habitats which are already deteriorated, or which have been lost. Tracking of status as well as of the efficiency of conservation efforts furthermore requires the development of harmonized monitoring and mapping techniques and standardized assessment methods.

Highlighted science needs

Habitat mapping

1.2.1. Development and testing of criteria for regionally coordinated mapping of habitats/biotopes, taking into consideration the relevant assessment needs, to facilitate data exchange and support national and regional assessments and reporting as well as Maritime Spatial Planning (MSP);

1.2.2. Development of widely applicable methods and tools to decrease the resource requirement and increase efficiency of habitat mapping.

1.2.3. Exploring substantiating the threshold setting rationale for certain pelagic habitat indicators using sediment archive studies and paleo-ecology approaches.

1.2.4. Conducting eDNA based analyses of past phytoplankton and pelagic habitat communities to substantiate the threshold setting rationale for certain pelagic habitat indicators.

Pressure-impact assessment

1.2.5. Investigations on pressure-response relationships in benthic ecology, such as recovery time of benthic habitats after disturbance, to understand adverse effects of pressures on benthic habitats and to support the definition of threshold values and conservation measures;

1.2.6. Analysis of historical age and/or size distribution of long-lived species to establish an ecologically relevant baseline to support the setting of appropriate threshold values to indicate where pressures adversely affect benthic communities.

Ecosystem functions

1.2.7. Research on links between pelagic and benthic habitats/biotopes and ecosystem functions to better understand the role of benthic and pelagic components in ecosystem functioning, with a view to strengthening the ecological relevance of both assessments and management measures;

1.2.8. Development of criteria for estimating the contribution of pelagic and benthic habitats to ecosystem services to evaluate the benefit of healthy habitats to human wellbeing;

1.2.9. Analyses of the role of traits for the functioning of pelagic and benthic habitats/biotopes, including the link to food webs, with special focus on a changing climate and oxygen depletion, with a view to improving the holistic aspect of assessments and the causal link between pressures, impact and state.

1.2.10. Research to understand how ringed-seals haul out behaviour is affected by varying sea ice quality.

Habitat restoration

1.2.11. Identification of areas, as well as development and improvement of methods, for the restoration of benthic habitats/biotopes, e.g. habitat-forming species such as seagrass beds, macrophyte stands and reefs, along with improving the understanding of the wider synergistic effects of habitat restoration efforts, to support effective measures to improve biodiversity and nature based-solutions for tackling climate change and its impacts.

2 For example Rcommendation (Rec.) 40/1 Conservation And Protection Of Marine And Coastal Biotopes, Habitats And Biotope Complexes Categorized As Threatened According To The Helcom Red Lists; Rec. 28e/9 Development Of Broad-Scale Marine Spatial Planning Principles In The Baltic Sea Area; Rec. 35/1 System Of Coastal And Marine Baltic Sea Protected Areas (HELCOM MPAs, former HELCOM BSPAs).

1.3. Food webs

Species diversity is known to be low in the Baltic Sea due to its character as a young brackish sea with a prehistory as a freshwater lake. A consequence of low species diversity are relatively short food chains, which are more sensitive to disturbance and can be permanently altered by the disappearance of individual species. The open sea food web in the Baltic is characterized by a low number of food web interactions driven by a few key species, while the coastal food webs are comparatively more complex and diverse. Functionally diverse marine food webs are the basis of a healthy ecosystem, and also indicate the status of biodiversity. Food webs in the Baltic Sea as well as their components – species of flora and fauna – are impacted by various types of pressures either induced directly or indirectly by human activities, e.g. by climate change. At present, the status of the Baltic Sea food webs is inadequate and they are deteriorating despite management and governance measures (HELCOM 2018a). Both upper and lower levels of food webs need to be considered when assessing changes in predator-prey interactions as well as the larger scale variations of ecosystem functioning.

To improve the management of human activities and conservation efforts in the Baltic Sea, the need to understand processes between elements of the food webs is noted in several HELCOM reports and planning documents and reflected as an identified science need.

Highlighted science needs

Knowledge to support food web assessments

1.3.1. Improved understanding of key food-web states and processes which underlie critical and complex ecosystem dynamics to support assessment of the status of food webs;

1.3.2. Improved understanding of changes in trophic relationships, age categories and species composition of fish caused by fishery activities;

1.3.3. Better knowledge on benthic-pelagic coupling and associated food web implications from changes in benthic conditions caused by e.g. climate change.

Models to support development of measures

1.3.4. Development of dynamic food web models, including all relevant food web components (e.g. fish, mammals and birds), for detection of horizontal (plankton-benthos) and vertical (lower levels- upper levels) interactions, to guide the development of conservation and management measures.

1.4. Marine protected areas

Baltic Sea marine protected areas (HELCOM MPAs) are located where the conservation need is most urgent and where the potential benefit is highest. Especially a well-managed and ecologically coherent network is an important tool for fulfilling HELCOM ambitions for a healthy Baltic Sea. Such a network would potentially help to improve the resilience of the entire ecosystem to external threats such as eutrophication and climate change by protecting biodiversity. Large no-use zones are important aspects of such a network. However, despite considerable advances in the spatial coverage of MPAs in the Baltic Sea, there is still a lack in implementation of effective conservation measures, partly due to the inadequate understanding of complex ecosystem interactions.

The current HELCOM MPA network is neither complete, nor does it fulfil the requirements for coherence or proper management (HELCOM 2016). In order to fulfil the ambition of HELCOM work on MPAs, as well as the potential of the MPA network to help secure good environmental status, common methods for assessments of management effectiveness need to be developed, as does support to help guide the strategic expansion of the network to improve its ecological coherence.

Meeting the identified science needs would contribute directly to the implementation of the HELCOM Recommendation on System of Coastal and Marine Baltic Sea Protected Areas (HELCOM MPAs[3]).

Highlighted science needs

Evaluation of spatial protection measures

1.4.1. Development of scientific criteria to be used to identify potential no-take zones, with the aim of limiting the pressure stemming from fishing efforts and improving the state of biodiversity;

1.4.2. Quantifying the effectiveness of spatial conservation measures, especially the link between measures and change in state, to help guide conservation efforts;

1.4.3. Development of suitable scientific tools for a regular assessment of the effectiveness of spatial protection measures, i.e. how effective an area or network of areas is, e.g. through its location and extent, proximity to other areas, the species/diversity it hosts, its contribution to ecosystem services etc;

1.4.4. Establishment of criteria to assess management effectiveness, both for individual MPAs and the network as a whole, respectively, with the aim of identifying gaps in existing management efforts and improving management both in individual MPAs and across the network.

Ecological coherence

1.4.5. Establishment of science-based criteria and targets to be used for the HELCOM coherence assessment methodology;

1.4.6. Identifying parameters which justify the designation of new or expansion of existing MPAs in order to achieve and maintain coherence of the MPA network in relation to climate change;

1.4.7. Investigating the impact of climate change on protected areas, including modelling benthic habitats/biotopes and species distribution maps for the entire Baltic Sea region under different climate change scenarios, to use as one basis for planning and optimizing the MPA network and ensure coherence in the long term.

3 Former HELCOM BSPAs.

2. Human dimension

Humans are inextricably linked to the Baltic Sea ecosystem, on the one hand through the benefits they derive from its resources and, on the other, through the impacts of human activities on its state. Historic records of cod catches show a viable fishery dating back to the late 1500s although intense cod fishery started only in the 1950s. The onset of eutrophication in some coastal areas of the Baltic Sea dates back to approximately 1800 CE. During the last century the increasing human population and associated resource demand and the growing development of economic activities have, despite an increasing awareness and environmental regulations, resulted in an unsustainable use of the Baltic Sea as reflected in its current state (HELCOM 2018a).

Many sources of pollutants are land-based and the Baltic Sea, with its slow water exchange with the North Sea (approximately 40-50 years), large human population in the catchment area and proximity to intensive agriculture and industrialized regions, is heavily loaded by nutrients and a broad range of chemical pollutants, as well as litter. Sea-based activities are also contributing significantly to the pressures on the sea. Fisheries are the primary cause of human induced mortality of species in the Baltic, including for non-target species such as seals and birds. Shipping is an activity that contributes to many types of pressures, including specific pressures such as the introduction of non-indigenous species (NIS) through ballast water and the release of hazardous substances that are associated with shipping activities, including oil spills.

For the Baltic Sea, the Helsinki Convention forms the basis for joint protection of the sea from human activities and the HELCOM Contracting Parties have agreed on many measures to jointly curb and mitigate the impact of human activities on the environment. An example is the large number of joint HELCOM Recommendations, including for example limit values for the release of substances, guidelines on best available techniques (BAT) and best environmental practices (BEP), agreements on spatial restrictions for certain activities, and many others. While some activities and pressures have been studied for a long time in the Baltic Sea, the HELCOM Recommendations and other commitments still need continuous updates based on the latest scientific findings. For pressures such as marine litter and underwater noise, that have been given attention more recently, basic knowledge on sources and development of management measures is still needed.

This chapter focuses on research needs that need to be met to quantify the sources and levels of pressures as needed, define a sustainable use of marine resources, and to develop and evaluate measures to manage human activities. Better knowledge on expected changes in climate is central since it will need to be considered in the management of all aspects of the Baltic Sea, including adapting policies and taking measures to mitigate the anticipated long-term changes.

2.1. Climate change

Climate change has, and will have, a major impact on the marine environment and it poses a growing risk owing to the accelerated pace of change and interactions with other pressures. In the Baltic Sea region climate change will most likely result in increased temperatures and significant changes in other meteorological parameters such as precipitation, wind forcing and cloud cover. This will cause changes in hydrography and circulation in the sea, and the most likely changes are increased water temperature and decrease in ice cover. Furthermore, global sea level rise will affect the Baltic Sea coasts as well as the water exchange with the North Sea. Future salinities are uncertain although more evidence points toward a decrease than an increase, associated with a potential change in stratification. With increasing CO_2 concentration in the atmosphere acidification of the Sea is expected to increase over time.

These changes will most likely result in significant alterations of all components of the food chain from increased primary production due to faster surface water regeneration to seal population changes due to diminishing sea ice. Changing salinity, most probably decreasing, would have drastic effects on species distribution in the Baltic Sea.

Socioeconomic development is occurring concurrently and, in some cases, in response to climate change. Results showed that with regard to eutrophication the global and regional socioeconomic development can be as important as climate change itself in shaping the future Baltic Sea environment.

The ultimate aim of HELCOM work with regard to climate change is to increase and ensure the resilience of the Baltic Sea ecosystem to limit the impacts of a changing climate. The challenges presented by marine climate change are by their nature of international concern and the topic is cross-cutting, covering aspects from science to high-level policy. To achieve the aim set out under HELCOM the climate change work within the organization focuses on a long-term, multi-disciplinary approach to both understand and communicate the implications of climate change for the marine and coastal environment as well as to ensure that the information is integrated in HELCOM policies.

Highlighted science needs

2.1.1. Further development of regionalized scenarios of climate change effects on the marine physical environment (hydrography and circulation, sea level, sea ice, morphology) of the Baltic Sea as a basis for a wide range of scientific and managerial assessments, for example investigations of climate change impacts on the ecosystem and development of coastal adaptation strategies;

2.1.2. Further development of scenarios that illustrate the impact of multiple global and regional drivers (both socioeconomic development and climate change) on activities and resulting pressures in the Baltic Sea. One example would be to investigate how changing global food demand together with changed climate influence agriculture in the catchment and the subsequent leakage of nutrients to the Sea;

2.1.3. Development of ways to incorporate climate change aspects in the HELCOM Nutrient Reduction Scheme to ensure that BSAP eutrophication objectives can be reached also under conditions of climate change;

2.1.4. Research on the expected response of biota, biodiversity and ecosystem functioning to climate-induced changes of the physical and chemical environment, including responses to water temperature increase and changes to other relevant parameters, for example, salinity, oxygen, sea level and pH.

2.1.5. Research on how the dissolution of calcium carbonate from coastal and seabed erosion contributes to Total Alkalinity (AT) generation, to potentially explain the unresolved source of AT, which is crucial for better understanding the acidification of the Baltic Sea.

2.2. Eutrophication

Due to the cumulative effect of a century of high anthropogenic nutrient inputs the water quality of almost the entire Baltic Sea is severely impaired to a level that has strongly altered the ecosystem and caused significant benthic habitat loss. The status has not yet improved substantially despite long-term and partly successful efforts to reduce nutrient inputs. Continued reductions of nutrient inputs are needed to reach the ultimate target: a Baltic Sea unaffected by eutrophication.

Management of Baltic Sea eutrophication is complicated due to the slow response of the system manifested by up to decadal delays from the implementation of measures to improved open sea water quality. For this purpose, HELCOM uses results from mathematical models to estimate Maximum Allowable Inputs that are consistent with good environmental status as agreed in HELCOM. As a basis for the estimates there are several studies available on the combined effect of changes in nutrient input and climate change. Less studied on a Baltic Sea scale is the delay and efficiency of implementation of measures targeting diffuse sources in the catchment on the reduction of nutrient inputs via rivers. Increased knowledge on the effects of climate change on eutrophication processes are needed, both in the catchment area and the sea.

There are still demands for the development and implementation of additional measures to reduce the nutrient inputs from wastewater, agriculture, shipping and other sources. However, there is also still a lack of knowledge to optimally plan the measures needed to not only achieve reductions of nutrient inputs but also to cost-effectively improve the eutrophication status of the Baltic Sea.

Highlighted science needs

Input of nutrients

2.2.1. Improved and harmonized catchment modelling to determine the sources of nutrient inputs. The selection of appropriate measures to reduce the total nutrient inputs to the Baltic Sea basins can then be supported by quantification of the various anthropogenic sources versus the natural background.

2.2.2. Improved understanding of the relationship between nitrogen inputs and their concentrations in the sea, particularly focusing on changes in winter nutrient levels, the harmonisation between coastal and open sea threshold values, and the effects of climate change on these.

Measures to reduce nutrient input

2.2.3. Improved understanding and quantification of nutrient sources that lead to inputs to the sea and quantification of efficiency of measures that can curb these sources. This should result in estimations of reduction potential from different areas and sectors of the countries situated in the catchment area of the Baltic Sea;

2.2.4. Development of novel, efficient and environmentally sustainable techniques and practices to improve nutrient recycling and to minimize nutrient loads from diffuse sources.

2.2.5. Experimental and quantifiable studies that show what impact restoration can have on recovery from e.g. eutrophication, to help validate whether threshold and target values are realistic.

Nutrient cycling processes

2.2.6. Investigating the obstacles preventing the decrease of nutrient concentrations and contraction of hypoxic/anoxic areas in the sea. This encompasses improving the understanding of how the complex nutrient dynamics, including feedbacks with oxygen conditions, control the legacy of nutrients and whether there is potential in sea-based measures to accelerate recovery;

2.2.7. Improved understanding of the relationships between coastal and offshore eutrophication problems ensuring a solid scientific basis for optimal joint management of coastal and offshore eutrophication. This includes quantification of coastal retention/filter, and understanding and modelling of interactions between the coast and the open Baltic Sea.

2.2.8. Improved understanding of how nutrient concentrations and particularly phosphorus respond to ongoing climate change, to extreme hydrological events (e.g. floods and droughts) and expanding oxygen deficit areas.

2.3. Hazardous Substances

The hazardous substances that enter the Baltic Sea originate from various anthropogenic sources, especially from industries, consumer products, urban areas, submerged munition, agriculture and animal husbandry, as well as maritime activities. Just a small fraction of the chemicals that are emitted by society are monitored or screened. Consequently, the chemical composition in the Baltic Sea is not well characterized.

The most recent status assessment addressing hazardous substances indicates that status is not good overall and that due to the persistent nature of several of these substances it is likely that contamination will remain a significant pressure for an extended period. The majority of the chemicals used as indicators are legacy pollutants which are strictly regulated at the regional and/or global level and have been substituted by other less well-known compounds. In addition to comprehending the overall pool of potentially harmful substances entering the Baltic Sea, further efforts are warranted to assess the biological effect of the total chemical load on human health and ecosystems, including transformation products and in combination with other stressors. More knowledge regarding sources, emissions and dominant transport processes are needed to develop efficient measures that can reduce chemical pollution.

There are over 30 HELCOM Recommendations aimed at reducing the input of hazardous substances from land- and sea-based sources. In addition, HELCOM has developed an overview and analysis of the HELCOM framework and regional policy for hazardous substances. The overview includes recommendations for improving the framework as well as the strategic approach to HELCOM's work on hazardous substances.

Highlighted science needs

Input of and measures to reduce hazardous substances

2.3.1. Improved knowledge on the use patterns and emissions of hazardous substances from various sources, both land- and sea-based, and modelling of the relative importance of different transport routes to support the development of efficient measures targeting chemical contamination of the Baltic Sea in general, such as advanced wastewater- and storm water treatment, and identification of specific substance groups of concern;

2.3.2. Retrospective temporal trend analysis of emissions and environmental concentrations, e.g. through historic deposition in sediments or samples in biota banks, to assess the efficiency of implemented measures and interactions with multiple pressures and stressors - both legacy contaminants and contaminants of emerging concern;

2.3.3. Improved knowledge on submerged munition and historically dumped waste and its integrity (e.g. status of corrosion, leakage of the hazardous substances) per location including development of a risk assessment approach for marine environment (e.g. in biota, if applicable in sediment and water).

Status and effects of contaminants

2.3.4. Development and harmonization of monitoring methods based on biological effects, including bioassays for different endpoints at various levels and species targeting specific modes of action, that capture the impact of the total chemical mixture in the marine environment;

2.3.5. Development of methods that can link observed effects with causing agents (i.e. substances/mixtures) and/or trace to human activities causing release of contaminants associated with the effects observed in the environment;

2.3.6. Research on fate and transport of chemical contaminants in the marine environment under impact by multiple stressors, including eutrophication and climate change, and the effect that chemical contaminants (individual or mixtures) exert on key biological functions such as biogeochemical processes governing carbon and nutrient cycling.

2.3.7. Research to support a better understanding of how climate change interacts with hazardous substances and how this may influence the Baltic Sea ecosystem, to, amongst other things, support better contextualisation of indicator and assessment work (e.g., PBDEs, etc);

2.3.8. Research to better understand the impacts (e.g., effects and toxicity) hazardous substances of emerging concern, including pharmaceuticals such as diclofenac, to support appropriate risk evaluation and threshold value setting for indicators

2.3.9. Research to provide a stronger understanding of how bird flu impacts (or has impacted) on white-tailed sea eagle populations, to aid improved trend evaluations and help separate the impacts from those of hazardous substances and other factors in indicator evaluation.

2.4. Marine litter

Pollution of the marine environment by litter, and in particular plastics, is a global problem that was recognized already in the early 1970s while research in the Baltic started in early 2000s. Studies on the amount, types and distribution of macro- and microlitter are ongoing, including sampling of water, bottom sediments and on the coastline and beaches. To support comparability of data across the region common guidelines for beach litter surveys have been agreed in HELCOM. However, due to varying methodologies in water and sediment sampling, sample processing and laboratory analyses applied in different research institutes, the collected data especially for microlitter are not yet fully comparable, although this is foreseen to improve in the future due to the agreement of HELCOM guidelines for monitoring microlitter in the water column and in sediments in 2022. In addition, indicator species need to be defined in order to monitor and assess harm caused by marine litter, especially with regard to ingestion and entanglement. In this regard, work is ongoing on the drafting and testing of monitoring guidelines for microlitter in mussels which is expected to conclude in early 2025.

The 2021 revised HELCOM Regional Action Plan on marine litter, not only contains almost thirty regional actions designed to address land-based and sea-based sources of marine litter, but also identifies the gaps related to indicators and monitoring activities. These include improving knowledge concerning the sources of litter as well as to how to sample and assess the presence of litter in different compartments and its impact on biota.

Highlighted science needs

Development of monitoring

2.4.1. Development of a monitoring system for microplastics in biological organisms: identification of microplastics in the Baltic Sea food chain - from zooplankton to marine mammals and birds and humans.

Input, impact and fate of litter

2.4.2. Further identification and quantification of land- and sea-based sources and pathways of macro- and mesolitter and microplastics to support effective implementation of both preventive and mitigation measures;

2.4.3. Better understanding of the degradation and fragmentation processes of macro- to meso- and microplastics to understand the importance of the formation of secondary microplastics and potentially nanoplastics and related releases of additives into the marine environment and biota;

2.4.4. Research on the interactions of environmental conditions and natural factors like currents, winds, bottom topography, transfer in biota, river runoff, etc. and their influence on marine litter distribution;

2.4.5. Quantification of socioeconomic effects including human health implications from marine litter.

Mitigation measures

2.4.6. Evaluation of effectiveness and adaptation to regional needs of management actions, e.g. bans of plastics, improved wastewater treatment to remove microplastics, improved coastal waste management, application of Extended Producer Responsibility schemes, social awareness programmes and education, etc.

2.5. Underwater noise

Sound propagates effectively in water and various marine animals rely strongly on sound for communication, orientation and foraging. Noise from anthropogenic activities can also propagate far away from the source and affect communication (masking) and behaviour of animals, and if intense enough, even cause hearing loss and tissue damage. In the worst case, it can lead to death. Anthropogenic underwater noise is grouped into impulsive noise from e.g. explosions, seismic surveys, pile driving and sonars, and continuous noise, from ships and marine infrastructure (oil and gas platforms, offshore wind turbines etc.). Because the sources are well known less uncertainty relates to the pressure on the ecosystem, whereas the largest uncertainties relate to the impact. Assessing impact requires knowledge of how anthropogenic noise affects animals in their natural habitat, knowledge of the actual noise exposure of the animals, and knowledge of their abundance and spatiotemporal distribution. As a prerequisite to assessing impacts, it is also necessary to have proper knowledge of the spatiotemporal distribution of anthropogenic sources and their acoustic properties. In cases, where an impact is evident, there is a subsequent need for development and testing the effectiveness of mitigation measures as well as the assessment of their potential negative side effects.

Science needs related to impacts on animals - individuals as well as populations – are addressed in detail in the section on "Species". Science needs related to mitigating noise emissions from commercial shipping are addressed in the section on "Shipping". This section focuses on the noise itself, as a pressure factor and source of impact on marine ecosystems. The science needs closely reflect the needs arising from the measures committed to in the HELCOM Regional Action Plan for underwater noise.

Highlighted science needs

Impact of impulsive noise

2.5.1. Improved knowledge of pressures from sources currently not monitored, such as recreational activities/vessels, echosounders, sonars and sub-bottom profilers, to support assessment of impact both on small scale (EIAs on specific projects) and large scale (sub-basin scale);
2.5.2. Development and refinement of methods to quantify impact from impulsive noise sources on animal populations, moving away from interim risk-based indicators to true impact indicators.

Sources and impact of continuous low frequency noise

2.5.3. Improvement of methods for long-term acoustic monitoring, including modelling in shallow waters, taking into consideration work done in relevant fora;
2.5.4. Development or adaptation of methods to include contributions from smaller recreational vessels and static sources in modelling;
2.5.5. Adaptation of methods to incorporate the continuous low-frequency noise from offshore windfarm installations into continuous noise models, especially given the expected increase in such developments;
2.5.6. Expansion of knowledge of metabolic and physiological consequences of disturbances caused by vessels noise;
2.5.7. Development and refinement of methods to quantify impact from continuous noise sources on animal populations, moving away from interim risk-based indicators to true impact indicators;
2.5.8. Encouraging studies on the impact of climate change on the underwater soundscapes (direct and indirect effects of changes in sea level, hydrography and ice conditions) in order to improve the precision of forecasted scenarios involving underwater noise sources.

Mitigation measures for impulsive sound

2.5.9. Development or adaptation of effective noise abatement methods applicable to underwater explosions and/or alternatives to detonation;
2.5.10. Development and testing of technical and operational measures to reduce impact from other impulsive sources.

2.6. Non-indigenous species

The spread of non-indigenous species (NIS) is a global problem that affects most ecosystems and is among the greatest threats to biodiversity. The damage to biodiversity caused by the spread of NIS is often irreversible as aquatic NIS are considered impossible to eradicate after they have established themselves in the ecosystem. The Baltic Sea is shallow, young, semi-enclosed and brackish, which results in low species diversity and consequently incomplete occupancy of niches. This, in combination with the intense marine traffic, makes the Baltic Sea especially prone to the introduction and settlement of NIS.

Marine NIS most often enter the Baltic Sea with the ballast water of ships or as biofouling on the ships' hulls and harbours and ports are therefore hotspots for the introduction of NIS . The main vectors for freshwater NIS are canals, shipping and aquaculture.

The introduction of NIS through shipping is addressed in the dedicated section on 'Shipping' while this section is focused on the general needs to improve knowledge for the purpose of assessing the introduction and status of NIS and their impacts on other ecosystem components.

Highlighted science needs

Assessment of NIS

2.6.1. Development of reliable species identification methods, including molecular methods such as eDNA and development of DNA barcodes for Baltic Sea NIS, which would improve monitoring efforts;

2.6.2. Comprehensive understanding of the dynamics of spread for NIS in the Baltic Sea, to support the assessment of abundance, spatial distribution, and establishment, and, where necessary, the implementation of preventative measures.

Impacts of NIS

2.6.3. Better understanding of the effects of small NIS taxa such as protozoa, bacteria, and viruses. They remain unrecognized, undetected and are not prioritized in surveying of NIS, and knowledge on their impact is thus limited;

2.6.4. Development of methodologies to quantify the impact of NIS on ecosystem functioning, including for communities, biological processes and habitats, and on the ecosystem's carrying capacity and resilience. Improved knowledge would support the development of an indicator on adverse effects by NIS;

2.6.5. Research on the impacts of NIS on ecosystem services, health and other socio-economic aspects.

2.7. Shipping

During the last decades, the number and size of ships sailing the Baltic Sea have continuously increased and thereby their potential pressures on marine environment and atmosphere are becoming more intense.

Impacts of shipping are caused e.g. by air emissions, sewage, introductions of non-indigenous species (NIS), underwater noise and accidental or illegal discharges of oil. In addition, shipping accidents may occur, which can lead to significant environmental threats. In order to minimize environmental harm, many regulations have been adopted and partially already entered into force. Given the unique and sensitive environmental conditions of the Baltic Sea, it is designated by the IMO as a Special Area under MARPOL Annexes I, IV and V, and as a sulphur oxides (SOx) and nitrous oxides (NOx) emission control area under MARPOL Annex VI. Thus, it is provided with a higher level of protection than other sea areas.

Some of the pressures have already been addressed, others require the development and implementation of new measures. With regard to shipping, HELCOM aims at ensuring efficient and harmonized regional implementation of IMO regulations (e.g. MARPOL and BWMC). In addition, initiatives supporting the work at the international level are regionally developed. Further research activities are essential to advance and improve environmental standards, monitoring and assessment, as well as to evaluate the effectiveness of potential mitigation measures and to develop innovative sustainable technologies.

Highlighted science needs

Pressures and impacts from shipping

2.7.1. Development of tools for real-time information and smart monitoring of underwater noise emission;
2.7.2. Quantification of the amount of oil released into the Baltic Sea from small but continuous emissions of mineral oils and assessment of the environmental effects to assess the need for more stringent regulation;
2.7.3. Evaluation of effects and consequences of sewage discharges from cargo vessels;
2.7.4. Evaluation and estimation of volumes of discharges of harmful cargo residues into the Baltic Sea;
2.7.5. Research on the impact and management of food waste from ships in the Baltic Sea;

Development of measures to reduce pressures from shipping

2.7.6. Development of technical- and management options and evaluation of impacts of grey water discharges from vessels, in particular from passenger and cruise ships;
2.7.7. Identification and feasibility assessment of Best Available Techniques (BAT) and Best Environmental Practice (BEP) for underwater noise reduction;
2.7.8. Research and development activities in the context of the 2023 IMO strategy to reduce greenhouse gas emissions from ships;
2.7.9. Development of risk assessment and standards with respect to in-water cleaning (IWC) of commercial ships and leisure boats.

Implementation and enforcement of measures to reduce pressures from shipping

2.7.10. Research on indicative sampling of ballast water for BWMC D-2 compliance monitoring in the context of the IMO BWM Experience Building Phase;
2.7.11. Mapping of future needs of oil combatting capacity with a view to ensuring operational functionality of oil combatting operations regardless of season;
2.7.12. Better understanding and consideration of the human factor in the maritime traffic risk forecasting system to make it more reliable;
2.7.13. Research on the importance of electronic failures, human-machine interaction, and the autonomous ship concept.

2.8. Fisheries

The Baltic Sea hosts a unique combination of marine and freshwater species and habitats, and sustains diverse fisheries targeting a variety of species. The largest share belongs to herring, sprat, and cod. The ecosystem is characterized by a poor conservation status of several fish stocks, resulting in low catch quotas. Moreover, gillnet fisheries generate considerable amounts of bycatch, including endangered species, and bottom trawling causes disturbance to sensitive benthic habitats. A large proportion of the fleet in the Baltic Sea consists of small-scale fisheries.

There are currently too few data available to quantitatively assess the impacts of fisheries on the Baltic Sea. Improved reporting as well as research on fisheries impacts and mitigation measures are needed to improve fisheries management so that, in combination with mitigation of other factors which impact the fish stocks, a good status of habitats and species and achieving ecologically sustainable fisheries can be reached.

Research on the characteristics of fish populations, impact of fisheries, and conservation measures that can counteract impacts of fisheries are also addressed in Chapter 1 on Biodiversity.

HELCOM has develop the HELCOM Roadmap on fisheries data, which aims to target the gaps in data needed for quantitative assessments of fisheries impacts on the ecosystem.

Highlighted science needs

Impacts of fishing and other pressures affecting fish stocks:

2.8.1. Intensified research on bycaught species of all métiers to assess bycatch rates of seabirds, marine mammals and protected fish species;
2.8.2. Applied research on alternative methods for assessing and managing commercial fish stocks for their sustainable use;
2.8.3. Research on monitoring methods and management of coastal fisheries and fish species with little or no economic value, including freshwater populations, to preserve local fish stocks;
2.8.4. Analysis of non-fisheries related pressures affecting fish stocks in order to identify complementary measures.
2.8.5. Improved mechanistic understanding of how fishing (both commercial and recreational) and natural predation, impact coastal fish in local contexts, to help managers effectively address the declining trends of coastal fish species.

Bycatch mitigation measures:

2.8.6. Intensified research on bycaught species of all métiers in order to advance bycatch mitigation measures;
2.8.7. Development of new technical measures, alternative gear and modifications to existing gear to decrease bycatch of seabirds, marine mammals and protected fish species.

Evaluation of the effectiveness of measures:

2.8.8. Analysis and determination of the recovery process of benthic habitats and species in areas closed for fishing to assess management effectiveness;
2.8.9. Calculation/modelling of socio-economic aspects of fisheries affecting benthic habitats and fisheries management options throughout different métiers, performance of cost-benefit analyses;
2.8.10. Evaluation of management measures (e.g. spatial-temporal closures of fisheries, No-take areas) to avoid or reduce bycatch of threatened and declining species.

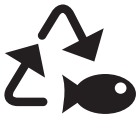
3. Holistic approaches

The previous chapters have focused on the knowledge and research needs related to specific species, communities, pressures and activities. In the context of this document these topics have been presented separately, while in reality they are interlinked and successful management requires the consideration of all of these aspects in a holistic way.

HELCOM work is based on the 'ecosystem approach' (EA), a concept originally developed under the UN Convention on Biological Diversity. HELCOM furthermore promotes 'ecosystem-based management' (EBM) of human activities, which incorporates the entire ecosystem, including humans, into management with the aim of achieving long term sustainable use of the ecosystem and required protection of the marine environment. Essential information for implementing these holistic approaches includes knowledge on the distribution and magnitude of pressures and their impacts on the ecosystem. Economic and social analyses provide a link between the ecosystem and the human dimension, for example through analyses of the benefits in terms of ecosystem services and revenues from economic sectors. The implementation of the EA and EBM furthermore requires that that the concepts are translated into practice. For this purpose, maritime spatial planning (MSP) can provide a tool for arranging and integrating different uses of the sea.

Management according to EA principles is still very much developing and evaluations of its realization and achievements is largely missing, in the Baltic Sea region and worldwide.

This chapters captures knowledge and research needs that are specifically linked to holistic approaches while highlighted science needs of an integrated nature are also represented under the other chapters, for example Food webs and Climate change.



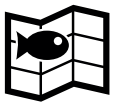
3.1. Ecosystem approach

At their Joint Ministerial Meeting 2003 in Bremen, Germany, HELCOM and OSPAR agreed on the following common definition of the Ecosystem Approach for their convention areas: *"The comprehensive integrated management of human activities based on the best available scientific knowledge about the ecosystem and its dynamics, in order to identify and take action on influences which are critical to the health of marine ecosystems, thereby achieving sustainable use of ecosystem goods and services and maintenance of ecosystem integrity"*. This includes the application of the precautionary principle. The ecosystem approach (EA) is advanced in HELCOM through the implementation of the Baltic Sea Action Plan and other HELCOM commitments.

Although the EA is a frequently used term and many principles for its implementation have been developed, there are many unresolved issues that require in-depth scientific investigation, in particular for the marine environment. The broad vertical and horizontal scope of EA has proven to be one of the main barriers to improved implementation, necessitating better cross-sectoral integration, cooperation and coherence at the international, regional, national and local levels. Improved communication, knowledge and capacity building on EA and the consequent ecosystem-based management (EBM), at all levels and involving stakeholders, are needed to increase understanding, including through improved science-practice collaboration. EBM implementation requires a holistic approach, based on holistic scientific advice. Currently, scientific input to policies tends to concentrate on the biophysical system and on environmental questions rather than the management of activities.

Highlighted science needs

3.1.1. Evaluation of in what way and how far the EA, i.e. the management of human activities in the Baltic Sea Region, has been implemented;
3.1.2. Establishing rules of procedure and approaches for implementation of the precautionary principle in the EA, ensuring that such procedures and approaches are compatible with those used under other assessments;
3.1.3. Investigating how the provisions of the Paris Agreement, adopted under the United Nations Framework Convention on Climate as a response to the threat of climate change, can be incorporated into the EA concept for the Baltic Sea;
3.1.4. Evaluation of approaches, measures and instruments to improve the state of the Baltic Sea towards good environmental status through application of the EA;
3.1.5. Development and improvement of Decision Support Tools that can perform qualitative and quantitative analysis to support implementation of the EA to management of human activities.



3.2. Maritime spatial planning

In 2010, the ecosystem approach was incorporated into 10 common maritime spatial planning (MSP) principles by HELCOM and Vision and Strategies Around the Baltic Sea (VASAB), where the EA is considered as an overarching principle. In 2016 a HELCOM and VASAB Guideline was developed to address the implementation of an ecosystem-based approach in maritime spatial planning in the Baltic Sea area. In recent years the implementation of the EA in MSP has been further developed through joint regional projects.

MSP in the Baltic Sea countries applies the EA on a general level, as is required in the HELCOM MSP roadmap 2013-2020 and in the EU Directive on MSP (2014/89/EU), but none of the countries can be said to have taken the EA as the cornerstone of their MSP. A factor that remains to be developed, despite significant progress in research and conceptual aspects of the ecosystem approach in the Maritime Spatial Planning field, are fully-fledged test cases of the EA in the MSP. Such test cases should be supported by strong, multidisciplinary research to facilitate future practical implementation of the EA. Such research would also support the implementation of the updated HELCOM MSP Roadmap, which has a strong emphasis on the EA.

Highlighted science needs

3.2.1. Identifying an appropriate collection of transparent spatial planning tools for a comprehensive consideration of ecosystem components;
3.2.2. Investigating how maritime spatial planning, applying the guiding principles of the EA, can incorporate independent sectoral plans into a regional and holistic plan that is fully aligned with conservation and good status objectives in the Baltic Sea region;
3.2.3. Establishment of processes with the ultimate goal of comprehensive marine, ecosystem-oriented planning for the Baltic Sea area;
3.2.4. Identify how MSP can support conservation and sustainable use in an equitable way reflecting marine protected areas (MPAs) and possible Other Effective Area-based Conservation Measures (OECMs) or other areas of high natural values in maritime spatial plans in order to steer harmful activites away from such areas;
3.2.5. Identify possibilities for MSP to support the BSAP targets related to protected areas as well as national and regional strategies.

3.3. Spatial pressure and impact assessments

Human activities in the Baltic Sea and its catchment area create a variety of pressures, potentially leading to negative impacts on the environment. If each of the pressures is considered individually, they may appear to occur at levels that do not cause harm to the environment. However, when considering their spatial and temporal distribution, their relation to specific ecosystem components, or in a cumulative manner, their impact may be considerable. Spatial pressure and impact assessments can be used as a tool for implementing holistic environmental management and to support sustainable development. Thus, they can help identify the spatial and temporal distribution of pressures and impacts, whether a pressure affecting an area is direct or indirect, the proportional contribution of a pressure to the impact on a particular site or feature, as well as provide a link back to the activity or activities the pressure originally stems from. This in turn can be used to inform the planning and implementation of measures, prioritise management activities, support the use of the precautionary approach and as a risk assessment tool. It also provides a good platform for regional cooperation and transboundary work, including for spatial planning efforts.

The HELCOM Ministers agreed in their Brussels Ministerial Declaration 2018 to improve the understanding of impacts of human activities (HELCOM 2018b), including the cumulative effects, on the ecosystem and to use this information for strengthening the implementation of ecosystem-based management. For spatial pressure and impact assessment to reach its full potential there is a need for improved understanding of the links between activities, pressures and impacts, in particular the sensitivities of various ecosystem components to these pressures, but also for technical development for how to generate and make accessible the results of such assessments.

Highlighted science needs

3.3.1. Improved spatial modelling of activities, pressures and ecosystem components underlying the impact assessment to enable improved resolution of the pressure and impact maps, thus increasing their usability for management;

3.3.2. Development of a reliable method for the validation of the results of a pressure or impact assessment to improve the confidence of the assessments and by extension their applicability in management;

3.3.3. Improved understanding of the sensitivity of ecosystem components to various pressures, thus strengthening the link between pressure and change in state, with a view to supporting assessment, management actions and the setting of realistic conservation targets;

3.3.4. Improved understanding of the accumulation and synergistic or antagonistic effects of several pressures overlapping in space and time, to better guide management measures and provide context to results of other assessments.

3.3.5. Research is needed to increase the understanding of the in-situ relationship between status of benthic habitats (and their biotopes) in relation to the expected impacts generated via cumulative impacts.

3.4. Economic and social analyses

Economic and social analyses are needed to fully apply the EA in the Baltic Sea and to support the sustainable use of marine resources. They provide a set of tools for examining the interlinkages between the ecosystem and the economic and social systems, and contribute to ecosystem-based marine management, maritime spatial planning, pollution mitigation, and integration and implementation of effective measures and policies. The concept of ecosystem services includes measurable benefits that people can obtain from ecosystems and is therefore used as a tool in the economic and social analyses. The identification and valuation of ecosystem services provide an option to quantify the impacts of ecosystems on human welfare. They can thus be used to find the gaps and to contribute to the information pool necessary for sustainable use of these services. As a part of the World Ocean, the Baltic Sea supplies numerous ecosystem services that provide benefits for economic activities and existence.

Although the process of employing economic and social analysis in HELCOM assessments has already started, research is still needed for implementing relevant HELCOM decisions such as the Ministerial Declaration 2018 (HELCOM 2018b) the Roadmap for HELCOM work on economic and social analyses .

Highlighted science needs

3.4.1. Gaining a better understanding of how the status of the marine environment is related to changes in economic activities and how these are distributed spatially to support ecosystem-based management of human activities and maritime spatial planning;
3.4.2. Evaluation of the costs, effects and benefits of measures and policies to support the development of effective new measures and policies, e.g. the BSAP;
3.4.3. Research on the linkage of marine state components to ecosystem services, related values and benefits to provide information on the welfare impacts of ecosystem changes and support the development of effective policies, e.g. the BSAP;
3.4.4. Development of approaches for the integrated assessment of ecosystem services to provide more information on the links between the ecosystem and the social-economic system to support the implementation of the EA and marine policies;
3.4.5. Development and application of quantitative criteria to describe ecosystem services to improve knowledge on the extent of ecosystem services in the Baltic Sea and their changes;
3.4.6. Development and testing of approaches and tools for marine ecosystem accounting to provide additional information on the linkages between the ecosystem and economic system and improve the consideration of ecosystem values in decision-making, to support more effective policies;
3.4.7. Research on obstacles for the implementation of HELCOM agreements, including aspects related to governance, actors, sector activities and factors that influence the behaviour of private citizens, reflecting the diversity in geographic and socioeconomic characteristics across the region, with the aim to generate tools to support transformative change.
3.4.8. Identify potential data sources and carry out analyses of driving forces i.e. societal and environmental factors that, via their effect on human behaviour or environmental conditions, may influence activities, pressures or the state of the environment.

4. How the HELCOM Science Agenda can be implemented

Direct involvement of HELCOM

The majority of knowledge-enhancing activities takes place in the scientific institutions and universities in the HELCOM countries. HELCOM, does, however, have some possibilities for direct involvement in science-based projects through external funding mechanisms. Thus, HELCOM can act as the coordinator of projects with partners from the Contracting Parties, an approach that has been taken in a number of projects financed by the EU through calls linked to the Marine Strategy Framework Directive (MSFD). On a number of occasions HELCOM has furthermore acted as a partner in regionally coordinated projects that have been financed through EU Interreg programmes. When carrying out joint assessments or in order to take forward key issues, such as the development of indicators or pollution load compilations, HELCOM can also initiate projects based on funding by the HELCOM countries.

The Science Agenda provides a tool for prioritizing internal activities and for directing efforts towards the development of applications with HELCOM as a coordinator or partner. The possibilities for HELCOM to be directly involved in science projects is, however, limited in terms of the possibility to apply, administer and coordinate projects.

External initiatives

Since the implementation of the major part of the Science Agenda will depend on external funding resources and the participation of experts from the Member countries, it is primarily a way of communicating HELCOM science needs to bodies external to HELCOM. The Science Agenda therefore aims at:

- encouraging scientists to apply for research projects linked to the highlighted knowledge needs,
- inviting external funding bodies to consider HELCOM knowledge and science needs in their planning of calls for application, including:
  - national authorities and agencies and private foundations that are funding research in the field of environment and sustainable development,
  - organizations responsible for regional funding programmes focusing on the marine environment, such as the European Commission and JPI Oceans;
- increasing interaction between policy and science.

HELCOM will also provide the Science Agenda as a contribution to the UN Decade of Ocean Science, which will run from 2021-2030. The aim of the UN initiative is to create a common ocean science framework that can support countries in achieving the UN Sustainable Development Goals and turn scientific knowledge and understanding into effective actions to support a sustainable development. In Annex 2 to this report the links between the knowledge needs highlighted in this report and the strategic objectives of the Decade of Ocean Science can be found. By supporting the UN Decade of Ocean Science, Baltic Sea countries can provide the necessary scientific underpinnings for future HELCOM work, including the implementation of the updated BSAP and the UN Sustainable Development Goals.

Many of the HELCOM knowledge and science needs are linked to the development of common approaches and a common basis for developing new and implementing existing HELCOM agreements. Funding programmes that support regional projects are therefore essential since they give scientists from various Baltic Sea countries the opportunity to work together already in the formulation phase of projects, in their implementation, as well as in the communication with stakeholders such as HELCOM.

The joint Baltic Sea research and development programme BONUS, funded by the EU and research funding institutes of the eight EU Member States of the Baltic Rea region, significantly boosted knowledge on the Baltic Sea social-ecological system during its implementation (2011-2017). The ongoing project 'The Baltic and North Sea Coordination and Support Action BANOS', is developing the foundation for a new research and innovation programme with similar funding mechanisms but now geared towards both Baltic Sea and North Sea. If realized, the identified objectives of the new programme could support part of the HELCOM Science Agenda, in particular the more research-intensive knowledge needs. A funding programme oriented towards both Baltic Sea and North Sea will also support further joint studies and development work between the two regional seas, activities that are strongly encouraged by the Commissions of the respective marine convention.

Proposed further reading

Selected reference list

HELCOM 2013. HELCOM Red List of Baltic Sea species in danger of becoming extinct. Baltic Sea Environment Proceedings 140.

HELCOM 2013. Red List of Baltic Sea underwater biotopes, habitats and biotope complexes. Baltic Sea Environment Proceedings 138.

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HELCOM 2023b. HELCOM Thematic assessment of biodiversity 2016-2021. Baltic Sea Environment Proceedings 191.

HELCOM 2023c. HELCOM Thematic assessment of eutrophication 2016-2021. Baltic Sea Environment Proceedings 192. H

HELCOM 2023d. HELCOM Thematic assessment of hazardous substances, marine litter, underwater noise and non-indigenous species 2016-2021. Baltic Sea Environment Proceedings 190.

HELCOM 2023e. Thematic assessment of economic and social analyses 2016-2021. Baltic Sea Environment Proceedings 188.

HELCOM 2023f. Thematic assessment on Spatial Distribution of Pressures and Impacts Assessment 2016-2021. Baltic Sea Environment Proceedings 189.

Pan Baltic Scope. Synthesis Report on the Ecosystem Approach to Maritime Spatial Planning. http://www.panbalticscope.eu/wp-content/uploads/2019/12/PBS-Synthesis-Report.pdf

Annex 1. Countries and HELCOM subsidiary bodies that have contributed

The Science Agenda is largely based on a survey that was distributed to all HELCOM expert networks, task groups and expert projects in spring and autumn 2019. Contributions were received according to the list below. The survey results have also been discussed at HELCOM Working Group meetings with the opportunity to complement the proposals.

- Expert network work on benthic species and habitats (EN Benthic),
- Expert network on economic and social aspects (EN ESA), prepared by the chair, Finland, Estonia, Latvia, Lithuania and Germany,
- HELCOM-OSPAR-ICES Joint Working Group on seabirds (JWG Birds), prepared by the chair and with input from Germany and Sweden,
- Expert network on Underwater Noise (EN Noise), prepared by the chair, based on the implementation of the draft HELCOM roadmap on underwater noise,
- Expert Group on Marine Mammals (EG MAMA),
- Reduction Scheme Core Drafting Group/ Pollution Load Compilations (RedCoreDG/PLC),
- Expert network on hazardous substances (EN Hazardous substances),
- Intersessional network on eutrophication (IN EUTRO)
- Project for Baltic-wide assessment of coastal fish communities (FISH-PRO project).
- Denmark with regard to non-indigenous species and marine litter,
- Germany (BfN), focusing on monitoring and nature conservation, with additional input from Germany related to non-indigenous species from shipping,
- Poland, with regard to agriculture,
- Finland, with regard to MPAs.

Annex 2. Links to HELCOM agreements and UN commitments

The examples given in this annex include mapping of the knowledge and science needs vs:

— type of knowledge needs (e.g. if they are related to indicators, pressure targets, development of measures, models etc),
— link to HELCOM agreements and activities,
— link to the DAPSIM concept,
— link to the UN Decade of Ocean Science and UN Sustainable development goals.

The aim is to provide more information to scientists that may have an interest in applying for funds related to the Science Agenda but also for further HELCOM work by linking the Science Agenda to current concepts and ongoing activities. This mapping is carried out against the level of highlighted science needs as presented in the main report.

Terms used in the mapping

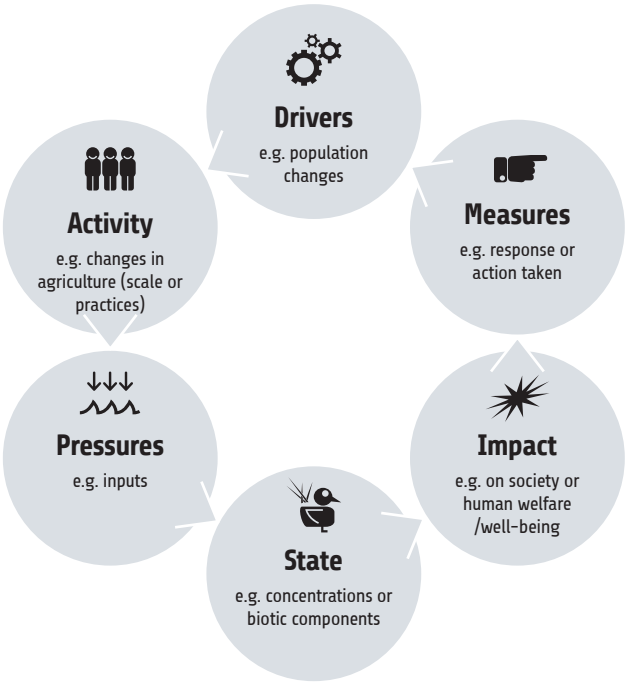
On top of each the link to the agreed objectives of the BSAP, adopted in 2021, are listed, including ecological objectives and management objectives.

BSAP segment colour codes
— Biodiversity
— Eutrophication
— Hazardous substances and litter
— Sea-based activities

HELCOM commitments
This column indicates selected HELCOM commitments whose implementation will benefit if the identified knowledge need is resolved.

— Rec: HELCOM Recommendations (in full at: https://helcom.fi/helcom-at-work/recommendations/)
— MD 2018: HELCOM 2018 Ministerial Declaration (in full at: https://helcom.fi/helcom-at-work/ministerial-meetings/2018-brussels/)
— BSAP: where appropriate, specific BSAP 2021 actions supported by or linked to the identified science need, are indicated. The BSAP actions are specified by a letter and a number which are associated to specific actions in BSAP 2021.
— General longstanding commitments by HELCOM, e.g. development of indicators, monitoring, assessments etc.

DAPSIM
For use in HELCOM the DPSIR scheme the term "Activities (A)" has been added and the Response (R) has been modified to Measures (M) to as these are relevant aspect for purpose of HELCOM work while underlying "Drivers" are currently an emerging topic in HELCOMs work. The designations in the tables are linked to the type of knowledge/research while in a broader sense the knowledge needs may be linked to additional aspects of the DAPSIM scheme.



D — Drivers
A — Activities
P — Pressures
S — State
S/I — Impacts on state components
I — Social impacts (here also including development and implementation of social and economic analyses to support marine management)
M — Measure (measures, adaption to changes, here also including development, implementation and evaluation of management

Objectives UN Decade of Ocean Science
The link to the UN Decade of Ocean Science is made to the level of "objectives" that have been identified.

- A clean ocean where sources of pollution are identified and removed
- A healthy and resilient ocean where marine ecosystems are mapped and protected
- A predictable ocean where society has the capacity to understand current and future ocean conditions
- A safe ocean where people are protected from ocean hazards
- A sustainably harvested ocean ensuring the provision of food supply
- A transparent ocean with open access to data, information and technologies

UN Sustainable Development Goals (UN SDGs)
Targets of the UN SDGs with an immediate link to the Science Agenda are listed below. The full list of SDGs can be found at https://www.un.org/sustainabledevelopment/sustainable-development-goals/

- 9.4 By 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities
- 12.4 By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment
- 12.5 By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse
- 13.1 Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
- 13.2 Integrate climate change measures into national policies, strategies and planning
- 14.1 By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution
- 14.2 By 2020, sustainably manage and protect marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans
- 14.3 Minimize and address the impacts of ocean acidification, including through enhanced scientific cooperation at all levels
- 14.4 By 2020, effectively regulate harvesting and end overfishing, illegal, unreported and unregulated fishing and destructive fishing practices and implement science-based management plans, in order to restore fish stocks in the shortest time feasible, at least to levels that can produce maximum sustainable yield as determined by their biological characteristics
- 14.5 By 2020, conserve at least 10 per cent of coastal and marine areas, consistent with national and international law and based on the best available scientific information
- 14c Enhance the conservation and sustainable use of oceans and their resources by implementing international law as reflected in UNCLOS, which provides the legal framework for the conservation and sustainable use of oceans and their resources, as recalled in paragraph 158 of The Future We Want.

1.1 Species

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - Viable populations of all native species
  - Natural distribution and occurrence of plants and animals
  - Marine life is healthy
  - No harm to marine life from litter
  - No or minimal harm to marine life from man-made noise
  - No or minimal disturbance to biodiversity and the ecosystem
- Management objectives:
  - Minimize disturbance of species, their habitats and migration routes from human activities
  - Human induced mortality, including hunting, fishing, and incidental by-catch, does not threaten the viability of marine life
  - Effective and coordinated conservation plans and measures for threatened species, habitats, biotopes, and biotope complexes
  - Minimize noise to levels that do not adversely affect marine life
  - Ensure sustainable use of the marine resources

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
1.1.1	Better knowledge of species distribution, population sizes and ecology and habitat selection to support precise status assessments and establish how best to direct management measures.	Distribution, species attributes	Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 34E/1 (Bird Habitats), Rec 37/2 (threatened species), BSAP B8, BSAP B11, BSAP B12, BSAP B13, BSAP B22, BSAP B33	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2,14.5
1.1.2	A need for increased understanding of gene-flow and the interaction of the three populations of Ringed-seals are needed, to improve assessments.	method development, mapping	Rec 27/28-2 (Seals), BSAP B21, B31	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
1.1.3	Development and optimization of methodology for the assessment of: — water bird reproductive success, which accounts for various species groups and provides ecologically relevant information on status across groups; — abundance and distribution of harbour porpoises throughout the full range of the species. — health aspects that account for spatial and inherent variation between species for seals and harbour porpoises, inclusive of the impact of hazardous substances.	Indicators, status	Indicator development, assessments, Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals). BSAP B8, BSAP B15, BSAP B33 BSAP B35, BSAP S49, BSAP S52	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.1.4	Research on the impact of impulsive and continuous underwater noise on marine mammals, fish populations and benthic communities; in particular, long-term consequences of masking, disturbance and hearing loss on survival and reproduction of marine mammals, and population-level consequences of impact at different life stages in species with pelagic larvae.	Impacts, status	Indicator development, assessment, Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Regional Action Plan on Underwater Noise, BSAP B8, BSAP B15, BSAP B22, BSAP S57, BSAP S58, BSAP S59, BSAP S62, BSAP S63	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A clean ocean where sources of pollution are identified and reduced or removed.	14.2

1.1.5	Research on the impact of macrolitter and microplastics on species and communities.	Impacts, status	Indicator development, assessment. HELCOM Regional Action Plan on Marine Litter (RAP ML), BSAP B22, BSAP HL31	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A clean ocean where sources of pollution are identified and reduced or removed.	14.2
1.1.6	Evaluation of population level impacts of bycatch of all relevant species.	Impacts, status	Indicator development, assessment, Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 37/2 (Threatened species), BSAP B8, BSAP B14, BSAP B21, BSAP S43, BSAP S44, BSAP S45, BSAP S46, BSAP S48, BSAP S49	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.1.7	An improved understanding of marine mammals is needed, as they're at the top of the marine food web, which makes them sensitive to changes throughout the ecosystem, and changes in food webs on which they rely (and for which our current understanding is poor). This may be significant with potential changes in food availability and altered transfer of contaminants.	Pressure, ecosystem interactions, impact	Rec 27/28-2 (Seals), Rec 34E/1 (Bird Habitats), Rec 37/2 (threatened species), BSAP B21, B31		A predicted ocean where society understands and can respond to changing ocean conditions	14.2
1.1.8	Better knowledge for the development of effective species conservation plans, in particular for marine mammal, bird and fish populations.	Measures, development	Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 34E/1 (Bird Habitats), Rec 37/2 (Threatened species), MD 2018: para 44, BSAP B8, BSAP B11, BSAP B9, BSAP B14, BSAP B15, BSAP B16, BSAP B19, BSAP B20, BSAP B21, BSAP B22,	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.1.9	Development of approaches to quantifying the effectiveness of specific conservation measures for species.	Measures, evaluation	Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 34E/1 (Bird Habitats), Rec 37/2 (threatened species), MD 2018: para 44, BSAP B8, BSAP B11, BSAP B9, BSAP B14, BSAP B15, BSAP B16, BSAP B17, BSAP B18, BSAP B19, BSAP B20, BSAP B21, BSAP B22,	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.1.10	Research to define precautionary approach levels for seals in their management units.	Conservation, threshold value	Rec 27/28-2 (Seals) BSAP B19, BSAP B20	S, M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.1.11	Research to establish clear conservation objectives and quantifiable threshold values (such as Limit Reference Values and Target Reference Limits) for effective future evaluations and conservation efforts of species.	Monitoring, development, methodology	indicator development, Rec 17/2 (Harbour Porpoise), B8	M, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

1.2 Habitats

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - Natural distribution, occurrence and quality of habitats and associated communities
  - Activities affecting seabed habitats do not threaten the viability of species' populations and communities
- Management objectives:
  - Minimize disturbance of species, their habitats and migration routes from human activities
  - Effective and coordinated conservation plans and measures for threatened species, habitats, biotopes, and biotope complexes
  - Minimize loss and disturbance to seabed habitats

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
1.2.1	Development and testing of criteria for regionally coordinated mapping of habitats/biotopes, taking into consideration the relevant assessment needs, to facilitate data exchange and support national and regional assessments and reporting as well as Maritime Spatial Planning (MSP).	Mapping, methods	Rec 40/1 (Threatened habitats), assessment, BSAP B32, BSAP HT9, BSAP HT10, BSAP HT11,	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.2	Development of widely applicable methods and tools to decrease the resource requirement and increase efficiency of habitat mapping.	Mapping, methods	Rec 40/1 (Threatened habitats), assessment, BSAP B25, BSAP HT9, BSAP HT10, BSAP HT11	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.3	Exploring substantiating the threshold setting rationale for certain pelagic habitat indicators using sediment archive studies and paleo-ecology approaches	indicator, Threshold value, ecosystem interactions	indicator development, BSAP B26	S	A predicted ocean where society understands and can respond to changing ocean conditions	14.3
1.2.4	Conducting eDNA based analyses of past phytoplankton and pelagic habitat communities to substantiate the threshold setting rationale for certain pelagic habitat indicators	indicator, Threshold value, ecosystem interactions	indicator development, BSAP B26	S	A predicted ocean where society understands and can respond to changing ocean conditions	14.3
1.2.5	Investigations on pressure-response relationships in benthic ecology, such as recovery time of benthic habitats after disturbance, to understand adverse effects of pressures on benthic habitats and to support the definition of threshold values and conservation measures.	Impacts, status	Rec 40/1 (Threatened habitats), indicator development, contribution to ESA developments, BSAP B26,BSAP B29, BSAP B33, BSAP S65, BSAP S67, BSAP S68	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.6	Analysis of historical age and/or size distribution of long-lived species to establish an ecologically relevant baseline to support the setting of appropriate threshold values to indicate where pressures adversely affect benthic communities.	Impacts, status Species attributes	Indicator development, BSAP B10, BSAP B33, BSAP S65, BSAP S67, BSAP S68	P, S/I, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.7	Research on links between pelagic and benthic habitats/biotopes and ecosystem functions to better understand the role of benthic and pelagic components in ecosystem functioning, with a view to strengthening the ecological relevance of both assessments and management measures.	Ecosystem interactions	Rec 40/1 (Threatened habitats), assessment, contribution to ESA developments, BSAP B25	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2

1.2.8	Development of criteria for estimating the contribution of pelagic and benthic habitats to ecosystem services to evaluate the benefit of healthy habitats to human wellbeing.	Ecosystem services	Contribution to ESA developments, BSAP B25	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.9	Analyses of the role of traits for the functioning of pelagic and benthic habitats/biotopes, including the link to food webs, with special focus on a changing climate and oxygen depletion, with a view to improving the holistic aspect of assessments and the causal link between pressures, impact and state.	Impacts, status Functional traits,	Indicator development, assessment, BSAP B10,	P, S/I, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.2.10	Research to understand how ringed-seals haul out behaviour is affected by varying sea ice quality.	Impacts, climate change	BSAP B21, B31	P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
1.2.11	Identification of areas, as well as development and improvement of methods, for the restoration of benthic habitats/biotopes, e.g. habitat-forming species such as seagrass beds, macrophyte stands and reefs, along with improving the understanding of the wider synergistic effects of habitat restoration efforts, to support the effectiveness of measures to improve biodiversity and nature based-solutions for tackling climate change and its impacts.	Measures, development	Rec 40/1 (Threatened habitats), contribution to ESA developments, BSAP B27	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2

*The knowledge need is not linked to social impacts per se but can contribute to the development of social economic impact analyses.

1.3 Food webs

The knowledge will contribute to achieving BSAP:

— Ecological objectives:
  Functional, healthy and resilient food webs
— Management objectives:
  Reduce or prevent human pressures that lead to imbalance in the food web

	Highlighted knowledge needs	Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
1.3.1	Improved understanding of key food web states and processes which underlie critical and complex ecosystem dynamics to support assessment of the status of food webs.	Indicators, status	Indicator development, assessment, BSAP B33, BSAP B34	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.3.2	Improved understanding of changes in trophic relationships, age categories and species composition of fish caused by fishery activities.	Impacts, fisheries	Indicator development, assessment, BSAP B33, BSAP B34	P, S, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.2, 14.4.
1.3.3	Better knowledge on benthic-pelagic coupling and associated food web implications from changes in benthic conditions caused by e.g. climate change.	Impacts, interactions	Indicator development, assessment, BSAP B33, BSAP B34	P, S, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
1.3.4	Development of dynamic food web models, including all relevant food web components (e.g. fish, mammals and birds), for detection of horizontal (plankton-benthos) and vertical (lower levels- upper levels) interactions, to guide the development of conservation and management measures.	Models	Indicator development, assessment, BSAP B33, BSAP B34	S, M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A predicted ocean where society understands and can respond to changing ocean conditions.	14.2

1.4 Marine protected areas

The knowledge will contribute to achieving BSAP:

— Management objectives:
- Effectively managed and ecologically coherent network of marine protected areas
- Minimize disturbance of species, their habitats and migration routes from human activities

Highlighted knowledge needs		Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
1.4.1	Development of scientific criteria to be used to identify potential no-take zones, with the aim of limiting the pressure stemming from fishing efforts and improving the state of biodiversity.	Method development, measures	Rec 35/1 (MPAs), BSAP B1	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.2	Quantifying the effectiveness of spatial conservation measures, especially the link between measures and change in state, to help guide conservation efforts.	Method development, measures	Rec 35/1 (MPAs), BSAP B1, BSAP B2, BSAP B3	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.3	Development of suitable scientific tools for a regular assessment of the effectiveness of spatial protection measures, i.e. how effective an area or network of areas is, e.g. through its location and extent, proximity to other areas, the species/diversity it hosts, its contribution to ecosystem services etc.	Method development, evaluation of measures	Rec 35/1 (MPAs), BSAP B1, BSAP B2, BSAP B3	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.4	Establishment of criteria to assess management effectiveness, both for individual MPAs and the network as a whole, respectively, with the aim of identifying gaps in existing management efforts and improving management both in individual MPAs and across the network.	Method development, evaluation of measures	Rec 35/1 (MPAs), BSAP B3	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.5	Establishment of science-based criteria and targets to be used for the HELCOM coherence assessment methodology.	Method development, assessment	Rec 35/1 (MPAs), BSAP B1, BSAP B2, BSAP B6	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.6	Identifying parameters which justify the designation of new or expansion of existing MPAs in order to achieve and maintain coherence of the MPA network in relation to climate change.	Measures, development	Rec 35/1 (MPAs), BSAP B6, BSAP B7, BSAP HT1	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5
1.4.7	Investigating the impact of climate change on protected areas, including modelling benthic habitats/biotopes and species distribution maps for the entire Baltic Sea region under different climate change scenarios, to use as one basis for planning and optimizing the MPA network and ensure coherence in the long term.	Impacts, climate change	Rec 35/1 (MPAs), BSAP B1, BSAP B6, BSAP HT1	P, S/I, M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.5

2.1 Climate change

The knowledge will contribute to achieving BSAP:
— Horizontal actions

	Highlighted knowledge needs	Type	HELCOM Commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
2.1.1	Further development of regionalized scenarios of climate change effects on the marine physical environment (hydrography and circulation, sea level, sea ice, morphology) of the Baltic Sea as a basis for a wide range of scientific and managerial assessments, for example investigations of climate change impacts on the ecosystem and development of coastal adaptation strategies.	Scenario development, climate change	BSAP HT1, BSAP HT2, BSAP HT5	P, M	A predicted ocean where society understands and can respond to changing ocean conditions. A safe ocean where life and livelihoods are protected from ocean-related hazards.	13.2, 13,2, 14.3
2.1.2	Further development of scenarios that illustrate the impact of multiple global and regional drivers (both socioeconomic development and climate change) on activities and resulting pressures in the Baltic Sea. One example would be to investigate how changing global food demand together with changed climate influence agriculture in the catchment and the subsequent leakage of nutrients to the Sea.	Scenario development, cumulative pressures	BSAP HT1, BSAP HT2, BSAP HT4	D, A, P, S, I	A predicted ocean where society understands and can respond to changing ocean conditions.	13,2, 14.3
2.1.3	Development of ways to incorporate climate change aspects in the HELCOM Nutrient Reduction Scheme to ensure that BSAP eutrophication objectives can be reached also under conditions of climate change.	Adaptation of policy	BSAP HT2	P, M	A predicted ocean where society understands and can respond to changing ocean conditions.	13.2, 14.3
2.1.4	Research on the expected response of biota, biodiversity and ecosystem functioning to climate-induced changes of the physical and chemical environment, including responses to water temperature increase and changes to other relevant parameters, for example, salinity, oxygen, sea level and pH.	Response, ecosystem	BSAP HT1, HT2, BSAP HT5	P, S/I	A predicted ocean where society understands and can respond to changing ocean conditions.	14.3
2.1.5	Research on how the dissolution of calcium carbonate from coastal and seabed erosion contributes to Total Alkalinity (AT) generation, to potentially explain the unresolved source of AT, which is crucial for better understanding the acidification of the Baltic Sea.	Climate change, biogeochemical process	BSAP HT5	S	A predicted ocean where society understands and can respond to changing ocean conditions.	14.2, 13.3, 13.2

2.2 Eutrophication

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - Concentrations of nutrients close to natural levels
  - Clear waters
  - Natural level of algal blooms
  - Natural distribution and occurrence of plants and animals
  - Natural oxygen levels
- Management objectives:
  - Minimize input of nutrients from human activities

Highlighted knowledge needs		Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
2.2.1	Improved and harmonized catchment modelling to determine the sources of nutrient inputs. The selection of appropriate measures to reduce the total nutrient inputs to the Baltic Sea basins can then be supported by quantification of the various anthropogenic sources versus the natural background.	Models, input of nutrients	HELCOM Nutrient reduction scheme, BSAP E1, BSAP E2, BSAP E3, BSAP E4	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.2.2	Improved understanding of the relationship between nitrogen inputs and their concentrations in the sea, particularly focusing on changes in winter nutrient levels, the harmonization between coastal and open sea threshold values, and the effects of climate change on these.	Input of nutrients, sources of pressure	HELCOM Nutrient reduction scheme, BSAP E1, BSAP E2, BSAP E3, BSAP E4	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.2.3	Improved understanding and quantification of nutrient sources that lead to inputs to the sea and quantification of efficiency of measures that can curb these sources. This should result in estimations of reduction potential from different areas and sectors of the countries situated in the catchment area of the Baltic Sea.	Activity-pressure links	HELCOM Nutrient reduction scheme	A, P	A clean ocean where sources of pollution are identified and reduced or removed. A predicted ocean where society understands and can respond to changing ocean conditions.	14.1
2.2.4	Development of novel, efficient and environmentally sustainable techniques and practices to improve nutrient recycling and to minimize nutrient loads from diffuse sources.	Measures, development	HELCOM Nutrient reduction scheme HELCOM Nutrient recycling strategy,, Rec 23/5-Rev.1 (Reduction of storm-water discharges), BSAP E7, BSAPE8, BSAP E16, BSAP E19	M	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.2.5	Experimental and quantifiable studies that show what impact restoration can have on recovery from e.g. eutrophication, to help validate whether threshold and target values are unachievable or realistic.	Effectiveness of measures, Inputs of nutrients	BSAP E2, BSAP E1	P, S, M	A clean ocean where sources of pollution are identified and reduced or removed.	14.1

2.2.6	Investigating the obstacles preventing the decrease of nutrient concentrations and contraction of hypoxic/anoxic areas in the sea. This encompasses improving the understanding of how the complex nutrient dynamics, including feedbacks with oxygen conditions, control the legacy of nutrients and whether there is potential in sea-based measures to accelerate recovery.	Models, ecosystem response	HELCOM Nutrient reduction scheme MD 2018: para 25, 26	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.2.7	Improved understanding of the relationships between coastal and offshore eutrophication problems ensuring a solid scientific basis for optimal joint management of coastal and offshore eutrophication. This includes quantification of coastal retention/filter, and understanding and modelling of interactions between the coast and the open Baltic Sea.	Models, ecosystem interactions	HELCOM Nutrient reduction scheme	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.2.8	Improved understanding of how nutrient concentrations and particularly phosphorus respond to ongoing climate change, to extreme hydrological events (e.g. floods and droughts) and expanding oxygen deficit areas.	Impacts, climate change, Input of nutrients	HELCOM Nutrient reduction scheme, BSAP E2, BSAP E1	P, S	A clean ocean where sources of pollution are identified and reduced or removed. A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.1, 14.2

2.3 Hazardous substances

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - Concentrations of hazardous substances close to natural levels
  - All seafood safe to eat
  - Healthy marine life
  - Viable populations of all native species
  - Functional, healthy and resilient food webs
- Management objectives:
  - Minimize input and impact of hazardous substances from human activities
  - Reduce or prevent human pressures that lead to imbalance in the food web

Highlighted knowledge needs		Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
2.3.1	Improved knowledge on the use patterns and emissions of hazardous substances from various sources, both land-and sea-based, and modelling of the relative importance of different transport routes to support the development of efficient measures targeting chemical contamination of the Baltic Sea in general, such as advanced wastewater- and storm water treatment, and identification of specific substance groups of concern.	Models, sources of pressure	MD 2018: para 36 BSAP S31, BSAP S38, BSAP HL3, BSAP HL6, BSAP HL9	P, M	A clean ocean where sources of pollution are identified and reduced or removed.	12.4
2.3.2	Retrospective temporal trend analysis of emissions and environmental concentrations, e.g. through historic deposition in sediments or samples in biota banks, to assess the efficiency of implemented measures and interactions with multiple pressures and stressors - both legacy contaminants and contaminants of emerging concern.	Level of pressure Effectiveness of measures	MD 2018: para 35, BSAP HL22	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4
2.3.3	Improved knowledge on submerged munition and historically dumped waste and its integrity (e.g. status of corrosion, leakage of the hazardous substances) per location including development of a risk assessment approach for marine environment (e.g. in biota, if applicable in sediment and water).	Mapping, risk assessment	MD 2018: para 36 BSAP S34, BSAP S35	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4
2.3.4	Development and harmonization of monitoring methods based on biological effects, including bioassays for different endpoints at various levels and species targeting specific modes of action, that capture the impact of the total chemical mixture in the marine environment.	Impact on biota, method development	BSAP HL13, BSAP HL24, BSAP HL28	S/I	A clean ocean where sources of pollution are identified and reduced or removed.	12.4
2.3.5	Development of methods that can link observed effects with causing agents (i.e. substances/mixtures) and/or trace to human activities causing release of contaminants associated with the effects observed in the environment.	Impact on biota, method development, assessment	BSAP HL10, BSP HL13, BSAP HL22	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed. A predicted ocean where society understands and can respond to changing ocean conditions.	12.4

2.3.6	Research on fate and transport of chemical contaminants in the marine environment under impact by multiple stressors, including eutrophication and climate change, and the effect that chemical contaminants (individual or mixtures) exert on key biological functions such as biogeochemical processes governing carbon and nutrient cycling.	Impact on biogeochemical processes. multiple stressors,	BSAP HL13	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed. A predicted ocean where society understands and can respond to changing ocean conditions.	12.4
2.3.7	Research to support a better understanding of how climate change interacts with hazardous substances and how this may influence the Baltic Sea ecosystem, to, amongst other things, support better contextualisation of indicator and assessment work (e.g., PBDEs, etc).	Climate change, pressures	BSAP HL22, HT5	P, S	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.3.8	Research to better understand the impacts (e.g., effects and toxicity) hazardous substances of emerging concern, including pharmaceuticals such as diclofenac, to support appropriate risk evaluation and threshold value setting for indicators.	Ecosystem interactions, impact on biota, Pressures, Method development	BSAP HL2, HL1, HL10, HL 13, HL22	P, S	A clean ocean where sources of pollution are identified and reduced or removed.	14.1
2.3.9	Research to provide a stronger understanding of how bird flu impacts (or has impacted) on white-tailed sea eagle populations, to aid improved trend evaluations and help separate the impacts from those of hazardous substances and other factors in indicator evaluation.	Pressures, development	BSAP HL30	P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

2.4 Marine litter

The knowledge will contribute to achieving BSAP:

— Ecological objectives:
  - No harm to marine life from litter
— Management objectives:
  - Prevent generation of waste and its input to the sea, including microplastics
  - Significantly reduce amounts of litter on shorelines and in the sea

Highlighted knowledge needs		Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
2.4.1	Development of harmonized cost-efficient methodologies for monitoring microplastics in different matrices, including field sampling, sample pre-treatment and plastics identification in laboratory, to support the establishment of a regional monitoring programme.	Method development, status	Regional Action Plan on Marine Litter, BSAP HL32	S	A clean ocean where sources of pollution are identified and reduced or removed.	12.5,
2.4.2	Further identification and quantification of land- and sea-based sources and pathways of macro- and mesolitter and microplastics to support effective implementation of both preventive and mitigation measures.	Input of pressure, sources	Regional Action Plan on Marine Litter, BSAP HL32	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 12.5, 14.1
2.4.3	Better understanding of the degradation and fragmentation processes of macro- to meso- and microplastics to understand the importance of the formation of secondary microplastics and potentially nanoplastics and related releases of additives into the marine environment and biota.	Input of pressure, sources	Regional Action Plan on Marine Litter, BSAP HL31	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 12.5. 14.1
2.4.4	Research on the interactions of environmental conditions and natural factors like currents, winds, bottom topography, transfer in biota, river runoff, etc. and their influence on marine litter distribution.	Input of pressure, distribution	Regional Action Plan on Marine Litter, BSAP HL31	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 12.5, 14.1
2.4.5	Quantification of socioeconomic effects including human health implications from marine litter.	Impacts, socio-economic	Regional Action Plan on Marine Litter, BSAP HL31	I	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 12.5, 14.1
2.4.6	Evaluation of effectiveness and adaptation to regional needs of management actions, e.g. bans of plastics, improved wastewater treatment to remove microplastics, improved coastal waste management, application of Extended Producer Responsibility schemes, social awareness programmes and education, etc.	Measures	Regional Action Plan on Marine Litter, MD 2018: para 33, 34, Rec 23/5-Rev.1 (Reduction of stormwater discharges), BSAP HL31	M	A clean ocean where sources of pollution are identified and reduced or removed. A predicted ocean where society understands and can respond to changing ocean conditions.	12.4, 12.5, 14.1

2.5 Underwater noise

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - No harm to marine life from manmade noise
- Management objectives:
  - Minimize noise to levels that do not adversely affect marine life
  - Minimize disturbance of species, their habitats and migration routes from human activities

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
2.5.1	Improved knowledge of pressures from sources currently not monitored, such as recreational activities/vessels, echosounders, sonars and sub-bottom profilers, to support assessment of impact both on small scale (EIAs on specific projects) and large scale (sub-basin scale).	Input of pressure, sources	Regional Action Plan on underwater noise	P, S, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.2	Development and refinement of methods to quantify impact from impulsive noise sources on animal populations, moving away from interim risk-based indicators to true impact indicators.	Impacts, status	Indicator development MD 2018: para 38 BSAP S62	P, S, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.3	Improvement of methods for long-term acoustic monitoring, including modelling in shallow waters, taking into consideration work done in relevant fora.	Methods, monitoring	Regional Action Plan on underwater noise, BSAP S57, BSAP S63	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.4	Development or adaptation of methods to include contributions from smaller, recreational vessels and static sources in modelling.	Modelling, sources	Regional Action Plan on underwater noise, BSAP S63	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.5	Adaptation of methods to incorporate the continuous low-frequency noise from offshore windfarm installations into continuous noise models, especially given the expected increase in such developments.	Development, measures, indicator	Regional Action Plan on underwater noise, BSAP S58, BSAP S61	S, P	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.6	Expansion of knowledge of metabolic and physiological consequences of disturbances caused by vessel noise.	Impacts, status	Regional Action Plan on underwater noise, BSAP S57	P, S, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.7	Development and refinement of methods to quantify impact from continuous noise sources on animal populations, moving away from interim risk-based indicators to true impact indicators.	Impacts, status	Regional Action Plan on underwater noise, BSAP S58, BSAP S62	P, S, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.2

2.5.8	Encouraging studies on the impact of climate change on the underwater soundscapes (direct and indirect effects of changes in sea level, hydrography and ice conditions) in order to improve the precision of forecasted scenarios involving underwater noise sources.	Impacts, climate change	Regional Action Plan on underwater noise	P, S, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.9	Development or adaptation of effective noise abatement methods applicable to underwater explosions and/or alternatives to detonation.	Measures, development	Regional Action Plan on underwater noise, BSAP S59,BSAP S60, BSAP S61	M	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.5.10	Development and testing of technical and operational measures to reduce impact from other impulsive sources.	Measures, development	Regional Action Plan on underwater noise, BSAP S59, BSAP S60, BSAP S61	M	A clean ocean where sources of pollution are identified and reduced or removed.	14.2

2.6 Non-indigenous species

The knowledge will contribute to achieving BSAP:

— Management objectives:
No introductions of non-indigenous species

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
2.6.1	Development of reliable species identification methods, including molecular methods such as eDNA and development of DNA barcodes for Baltic Sea NIS, which would improve monitoring efforts.	Method development Level of pressure	MM 2018, BSAP S7, BSAP S11	P, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.6.2	Comprehensive understanding of the dynamics of spread for NIS in the Baltic Sea, to support the assessment of abundance, spatial distribution, and establishment, and, where necessary, the implementation of preventative measures.	Distribution, pressure	Indicator Proposed HELCOM Biofouling roadmap, MM 2018, BSAP S7, BSAP S8, BSAP S11, BSAP S12	P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.6.3	Better understanding of the effects of small NIS taxa such as protozoa, bacteria, and viruses. They remain unrecognized, undetected and are not prioritized in surveying of NIS, and knowledge on their impact is thus limited.	Impacts, on ecosystem	BSAP S11, BSAP S12	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.6.4	Development of methodologies to quantify the impact of NIS on ecosystem functioning, including for communities, biological processes and habitats, and on the ecosystem's carrying capacity and resilience. Improved knowledge would support the development of an indicator on adverse effects by NIS.	Impacts, on ecosystem	BSAP S10	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.6.5	Research on the impacts of NIS on ecosystem services, health and other socio-economic aspects.	Impacts, socio-economic	BSAP S10,	I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2

2.7 Shipping

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - No or minimal disturbance to biodiversity and ecosystem
  - Activities affecting seabed habitats do not threaten the viability of species' populations and communities
  - No harm to marine life from manmade noise
- Management objectives:
  - Minimize loss and disturbance to seabed habitats
  - Minimize noise to levels that do not adversely affect marine life
  - No introductions of non-indigenous species
  - Minimize the input of nutrients, hazardous substances and litter from sea-based activities
  - Enforce international regulations – no illegal discharges
  - Safe maritime traffic without accidental pollution
  - Effective emergency and response capabilities
  - Minimize harmful air emissions
  - Zero discharges from offshore platforms

Highlighted knowledge needs		Type	HELCOM commitment	DAPSIM	UN Decade of Ocean Science	UN SDG
2.7.1	Development of tools for real-time information and smart monitoring of underwater noise emission.	Level of pressure	BSAP S57, BSAP S58, BSAP S62, BSAP s63	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.2
2.7.2	Quantification of the amount of oil released into the Baltic Sea from small but continuous emissions of mineral oils and assessment of the environmental effects to assess the need for more stringent regulation.	Level of pressure	MM 2018: para 36	P	A clean ocean where sources of pollution are identified and reduced or removed.	12.4
2.7.3	Evaluation of effects and consequences of sewage discharges from cargo vessels.	Impacts	BSAP S14	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 14.1
2.7.4	Evaluation and estimation of volumes of discharges of harmful cargo residues into the Baltic Sea.	Level of pressure	BSAP S16	P		
2.7.5	Research on the impact and management of food waste from ships in the Baltic Sea.	Impacts	BSAP S18	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 14.1
2.7.6	Development of technical- and management options and evaluation of impacts of grey water discharges from vessels, in particular from passenger and cruise ships.	Impacts, Measures	BSAP S15	S/I, R	A clean ocean where sources of pollution are identified and reduced or removed.	12.4, 14.1
2.7.7	Identification and feasibility assessment of Best Available Techniques (BAT) and Best Environmental Practice (BEP) for underwater noise reduction.	Measures	BSAP S55, BSAP S57	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.7.8	Research and development activities in the context of the 2023 IMO strategy to reduce greenhouse gas emissions from ships.	Pressure	BSAP S25	P	A clean ocean where sources of pollution are identified and reduced or removed.	9.4, 12.4, 14.1

2.7.9	Development of risk assessment and standards with respect to in-water cleaning (IWC) of commercial ships and leisure boats.	Risk assessment, IWC	BSAP S8, BSAP S9, BSAP S10, BSAP S12	P	A clean ocean where sources of pollution are identified and reduced or removed.	14.2, 14c
2.7.10	Research on indicative sampling of ballast water for BWMC D-2 compliance monitoring in the context of the IMO BWM Experience Building Phase.	Methods development, pressure	BSAP S12	P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14c
2.7.11	Mapping of future needs of oil combatting capacity with a view to ensuring operational functionality of oil combatting operations regardless of season.	Measures	BSAP S31, BSAP S32, BSAP S38	M	A safe ocean where life and livelihoods are protected from ocean-related hazards.	
2.7.12	Better understanding and consideration of the human factor in the maritime traffic risk forecasting system to make it more reliable.	Assessment	BSAP S5, BSAP S6	P	A safe ocean where life and livelihoods are protected from ocean-related hazards.	
2.7.13	Research on the importance of electronic failures, human-machine interaction, and the autonomous ship concept.		BSAP S6, BSAP S24, BSAP S26, BSAP S29			

2.8 Fisheries

The knowledge will contribute to achieving BSAP:

- Ecological objectives:
  - Viable populations of all native species
  - No or minimal disturbance to biodiversity and ecosystem
  - Activities affecting seabed habitats do not threaten the viability of species' populations and communities
- Management objectives:
  - Minimize loss and disturbance to seabed habitats
  - Ensure sustainable use of the marine resources
  - Human induced mortality, including: hunting, fishing, and incidental bycatch, does not threaten the viability of marine life
  - Effective and coordinated conservation plans and measures for threatened species, habitats, biotopes, and biotope complexes

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
2.8.1	Intensified research on bycaught species of all métiers to assess bycatch rates of seabirds, marine mammals and protected fish species.	Mapping and collation of information on activity Level of pressure	HELCOM Roadmap on fisheries data, BSAP S43, BSAP S44, BSAP S45, BSAP S46, BSAP S48, BSAP S49	A, P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
2.8.2	Applied research on alternative methods for assessing and managing commercial fish stocks for their sustainable use.	Management, methods development	BSAP S40, BSAP S51,	P, S/I, M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.4, 14.2
2.8.3	Research on monitoring methods and management of coastal fisheries and fish species with little or no economic value, including freshwater populations, to preserve local fish stocks.	Monitoring/Management, methods development	BSAP S39, BSAP S40, BSAP S53	S/I, M	A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.2
2.8.4	Analysis of non-fisheries related pressures affecting fish stocks in order to identify complementary measures.	Mapping Measures, evaluation	Roadmap on fisheries data, BSAP S43, BSAP S44, BSAP S45, BSAP S46, BSAP S48, BSAP S49	P, M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.4, 14.2
2.8.5	Improved mechanistic understanding of how fishing (both commercial and recreational) and natural predation, impact coastal fish in local contexts, to help managers effectively address the declining trends of coastal fish species.	Pressures, development	HELCOM Rec 35/1 (MPAs), BSAP S42, BSAP S40, B3	P, M	A productive ocean supporting sustainable food supply and a sustainable ocean economy	14.2
2.8.6	Intensified research on bycaught species of all métiers in order to advance bycatch mitigation measures.	Measures	Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 37/2 (Threatened species), BSAP B8, BSAP B14, BSAP B21, BSAP S43, BSAP S44, BSAP S45, BSAP S46, BSAP S48, BSAP S49	P,M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.4, 14.2

2.8.7	Development of new technical measures, alternative gear and modifications to existing gear to decrease bycatch of seabirds, marine mammals and protected fish species.	Measures, development	Rec 17/2 (Harbour Porpoise), Rec 27/28-2 (Seals), Rec 37/2 (Threatened species), BSAP S43, BSAP S44, BSAP S46, BSAP S47	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.4, 14.2
2.8.8	Analysis and determination of the recovery process of benthic habitats and species in areas closed for fishing to assess management effectiveness.	Measures, evaluation	HELCOM Rec 35/1 (MPAs), BSAP S42, BSAP S53	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2, 14.4
2.8.9	Calculation/modelling of socio-economic aspects of fisheries affecting benthic habitats and fisheries management options throughout different métiers, performance of cost-benefit analyses.	Socio-economic impacts	BSAP S43, BSAP S52, BSAP S53	I	A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.2, 14.4
2.8.10	Evaluation of management measures (e.g. spatial-temporal closures of fisheries, No-take areas) to avoid or reduce bycatch of threatened and declining species.	Measures, evaluation	HELCOM Rec 35/1 (MPAs), BSAP S41, BSAP S43, BSAP S45, BSAP S46, BSAP S47, BSAP S53,	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2

3.1 Ecosystem approach

The knowledge will contribute to achieving BSAP:

- Ecological objectives: all
- Management objectives: all
- Horizontal actions

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
3.1.1	Evaluation of in what way and how far the EA, i.e. the management of human activities in the Baltic Sea Region, has been implemented.	Management, evaluation	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.1.2	Establishing rules of procedure and approaches for implementation of the precautionary principle in the EA, ensuring that such procedures and approaches are compatible with those used under other assessments.	Management, implementation	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.1.3	Investigating how the provisions of the Paris Agreement, adopted under the United Nations Framework Convention on Climate as a response to the threat of climate change, can be incorporated into the EA concept for the Baltic Sea.	Management, implementation	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.1.4	Evaluation of approaches, measures and instruments to improve the state of the Baltic Sea towards good environmental status through application of the EA.	Management tools, evaluation	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.1.5	Development and improvement of Decision Support Tools that can perform qualitative and quantitative analysis to support implementation of the EA to management of human activities.	Management tools, evaluations	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	

3.2 Maritime spatial planning

The knowledge will contribute to achieving BSAP:
— Horizontal actions

	Highlighted knowledge needs	Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
3.2.1	Identifying an appropriate collection of transparent spatial planning tools for a comprehensive consideration of ecosystem components.	Management tool	Regional MSP Baltic Roadmap 2021-2030	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.2.2	Investigating how maritime spatial planning (MSP), applying the guiding principles of the EA, can incorporate independent sectoral plans into a regional and holistic plan that is fully aligned with conservation and good status objectives in the Baltic Sea region.	Management tools	MSP roadmap, BSAP HT12	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.2.3	Establishment of processes with the ultimate goal of comprehensive marine, ecosystem-oriented planning for the Baltic Sea area.	Management, process	MSP roadmap, BSAP HT12	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.2.4	Identify how MSP can support conservation and sustainable use in an equitable way reflecting marine protected areas (MPAs) and possible Other Effective Area-based Conservation Measures (OECMs) or other areas of high natural values in maritime spatial plans in order to steer harmful activites away from such areas.	Management guidance Protection of biotopes	MSP roadmap, BSAP HT14	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.2.5	Identify possibilities for MSP to support the BSAP targets related to protected areas as well as national and regional strategies.	Management tool Identification of high natural values	MSP roadmap	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2

3.3 Spatial pressure and impacts assessment

The knowledge will contribute to achieving BSAP:
- Ecological objectives: all
- Management objectives: all

Highlighted knowledge needs		Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
3.3.1	Improved spatial modelling of activities, pressures and ecosystem components underlying the impact assessment to enable improved resolution of the pressure and impact maps, thus increasing their usability for management.	Modelling, pressures and impacts	Assessment, BSAP B31	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	
3.3.2	Development of a reliable method for the validation of the results of a pressure or impact assessment to improve the confidence of the assessments and by extension their applicability in management.	Pressure and impacts assessment, validation	Assessment, BSAP B31	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	
3.3.3	Improved understanding of the sensitivity of ecosystem components to various pressures, thus strengthening the link between pressure and change in state, with a view to supporting assessment, management actions and the setting of realistic conservation targets.	Impacts, sensitivity of ecosystem components	Assessment, BSAP B31	P, S/I, S	A clean ocean where sources of pollution are identified and reduced or removed.	
3.3.4	Improved understanding of the accumulation and synergistic or antagonistic effects of several pressures overlapping in space and time, to better guide management measures and provide context to results of other assessments.	Cumulative impacts	Assessment, BSAP B31	P, S/I	A clean ocean where sources of pollution are identified and reduced or removed.	
3.3.5	Research is needed to increase the understanding of the in-situ relationship between status of benthic habitats (and their biotopes) in relation to the expected impacts generated via cumulative impacts.	Indicator, method development	BSAP	P, S	A predicted ocean where society understands and can respond to changing ocean conditions	14.2

3.4 Economic and social analyses

The knowledge will contribute to achieving BSAP:
— Horizontal actions

	Highlighted knowledge needs	Type	HELCOM commitments	DAPSIM	UN Decade of Ocean Science	UN SDG
3.4.1	Gaining a better understanding of how the status of the marine environment is related to changes in economic activities and how these are distributed spatially to support ecosystem-based management of human activities and maritime spatial planning.	Link status-activity	ESA Roadmap MD 2018: para 50	A, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.4.2	Evaluation of the costs, effects and benefits of measures and policies to support the development of effective new measures and policies, e.g. the BSAP.	Measures, evaluation	ESA Roadmap, BSAP MD 2018: para 51	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A productive ocean supporting sustainable food supply and a sustainable ocean economy.	14.2
3.4.3	Research on the linkage of marine state components to ecosystem services, related values and benefits to provide information on the welfare impacts of ecosystem changes and support the development of effective policies, e.g. the BSAP.	Link status-ecosystem services	ESA Roadmap MD 2018: para 50	S/I, I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed. A predicted ocean where society understands and can respond to changing ocean conditions.	14.2
3.4.4	Development of approaches for the integrated assessment of ecosystem services to provide more information on the links between the ecosystem and the social-economic system to support the implementation of the EA and marine policies.	Methods development, ecosystem services	ESA Roadmap MD 2018: para 50	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.4.5	Development and application of quantitative criteria to describe ecosystem services to improve knowledge on the extent of ecosystem services in the Baltic Sea and their changes.	Methods development, ecosystem services	ESA Roadmap MD 2018: para 50	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.4.6	Development and testing of approaches and tools for marine ecosystem accounting to provide additional information on the linkages between the ecosystem and economic system and improve the consideration of ecosystem values in decision-making, to support more effective policies.	Methods development, ecosystem accounting	ESA Roadmap, BSAP MD 2018: para 50	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed.	14.2
3.4.7	Research on obstacles for the implementation of HELCOM agreements, including aspects related to governance, actors, sector activities and factors that influence the behaviour of private citizens, reflecting the diversity in geographic and socioeconomic characteristics across the region, with the aim to generate tools to support transformative change.	Measures, implementation	BSAP	M	A predicted ocean where society understands and can respond to changing ocean conditions.	14.2
3.4.8	Identify potential data sources and carry out analyses of driving forces i.e. societal and environmental factors that, via their effect on human behaviour or environmental conditions, may influence activities, pressures or the state of the environment.	Management tools, Indicator, method developing	BSAP	M	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

*) The knowledge need is not linked to social impacts per se but can contribute to the development of social economic analyses.