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Glossary

0. Introduction

[HELCOM – add brief box type information on what HELCOM is**]**

Why 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. Such commitments include for example development of common targets for reduction of pressures, joint guidelines for sustainable use of resources, implementation of measures, analyses of economic and social aspects of marine management, and assessing the state of the environment, as examples. 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 of HELCOM countries to reach good environmental status of the Baltic Sea, as updated in 2021;
- HELCOM Recommendations – agreements on measures to address certain pollution sources or areas of concern;
- Tasks assigned to HELCOM expert groups – including 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 is not a scientific body per se 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.

Added values of formulating a HELCOM Science Agenda is to concentrate 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 to highlight how the implementation 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 per se. 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 of developing the Science Agenda was a request to HELCOM expert groups, networks and Working Groups to identify the knowledge and research needs they have identified as seen necessary to implement HELCOM agreements in their respective area of work (Annex 1). This survey generated [200 contributions] that are collated in a comprehensive inventory of HELCOM knowledge and research needs and provided as supplementary material to this report.

A Task Group with national representatives was established to prepare a consolidated Science Agenda using the survey results as a starting point. The Task Group has drawn information from the survey contributions but also complemented them, including identification of knowledge needs with a more overarching perspective directed towards the implementation of the Ecosystem Approach, a fundamental principle of HELCOM work.

How to read the Science Agenda

Chapters 1-3 highlights principal HELCOM knowledge and research needs that are required to support the implementation of the BSAP and other HELCOM agreements by 2030 and is structured around priority topics for HELCOM work. Chapter 1, which focuses on the theme 'Biodiversity', presents the science and knowledge needs to better understand and develop methods to assess the status of and impacts on the Baltic Sea species and habitats and the development of direct measures used to improve their status. '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. '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 will all contribute to the implementation of the Ecosystem approach in the Baltic Sea (Figure X). Finally, Chapter 4 includes a reflection on how the implementation of the Science Agenda can be realized.

The annexes provide associated information to 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 UN Decade of Ocean Science.

[Some of the identified knowledge needs can likely be achieved through short-term desktop studies and synthesis while others will require longer-term research projects. Knowledge that is required in HELCOM within a shorter time-frame than 2030, for example those seen as needed for planned assessments in the short-term, are indicated in the Annexes as appropriate]

1. BIODIVERSITY

The Baltic Sea is renowned 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 seasonal changes in temperature and the strong gradients in salinity including from north-to-south, coastal-to-offshore, and surface-to-bottom in sub-basins where a jump layer of salinity, the halocline, prevails. 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 which 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 also regulation of 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, thus ensuring that these services are retained. The composition of species and communities also dictate 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 1900’s the Baltic Sea is impacted by numerous and increasing number pressures stemming from human activities. 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 mitigating of impacts on biodiversity is a key component of joint HELCOM work, including the common goal to have an ecologically coherent 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 2018).

This chapter focuses on knowledge needs 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 foremost addressed in the chapter on ‘Human dimension’.

1.1 Species

Species from all parts of flora and fauna in the Baltic Sea have been impacted by human-induced changes in the ecosystem. While several well-targeted measures to alleviate these pressures have been applied in the Baltic Sea and status has improved for several species, 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 directly e.g. through habitat deterioration via physical disturbance, and indirectly via contaminants and eutrophication, noise as well as presence of non-indigenous species. Various kinds of bycatch, 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 to both ensure that human activities can be managed at sustainable levels and to establish effective protection and conservation measures for Baltic Sea species and communities, ultimately securing good status of the environment.

The outlined knowledge needs are relevant for the implementation of numerous HELCOM recommendations related to the protection of threatened species in general as well the specific protection of seals, harbour porpoise and birds (see Box 1).

Highlighted science needs

Species distribution:

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

Indicators and impact of pressures:

- Development of status indicators for coastal fish communities, including size and age aspects of populations and distributional range of species; for bird populations considering the reproductive success; for marine mammals considering abundance and distribution for harbour porpoise and health related indicators for seals, as well as Environmental Quality Standards (EQS) for relevant hazardous substances regarding marine mammals.
- Research on impact of 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;
- Research on impact of macrolitter and microplastics on species and communities;
- Evaluation of population level impacts of bycatch of all relevant species.

Conservation plans:

- Better knowledge for development of effective species conservation plans, in particular for marine mammal, bird and fish populations;
- Development of approaches on how to quantify the effectiveness of specific conservation measures for species;
- Research to define precautionary approach levels for seals in their management units.

Box 1. Selected HELCOM Recommendations that would benefit from the highlighted science needs:	
17/2	PROTECTION OF HARBOUR PORPOISE IN THE BALTIC SEA AREA
27/28-2	CONSERVATION OF SEALS IN THE BALTIC SEA AREA
34E/1	SAFEGUARDING IMPORTANT BIRD HABITATS AND MIGRATION ROUTES IN THE BALTIC SEA FROM NEGATIVE EFFECTS OF WIND AND WAVE ENERGY PRODUCTION AT SEA
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 tightly interlinked, especially so in the shallow Baltic Sea. Inadequate status of species and communities is closely linked to changes in their physical habitat and its possibility to ensure food, protection and breeding 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, which in turn leads to oxygen depletion in deeper areas, thereby altering both pelagic and benthic biotopes and overall food web dynamics. For effective planning, to manage human activities sustainable as well as for habitat and biotope conservation, as required by the BSAP and HELCOM Recommendations, improved knowledge about interactions between pressures, habitat structure and ecosystem functions is needed. In addition there is a need for further development of measures to restore habitats which are already deteriorated or which have been lost. Follow up of status as well as the efficiency of conservation efforts furthermore requires development of harmonized monitoring and mapping techniques, as well as standardized assessment methods.

Improved knowledge on habitats will support the implementation of several HELCOM Recommendations related to the protection and management of the Baltic Sea environment (Box 2).

Highlighted science needs

Habitat mapping:

- Develop and test 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);
- Develop widely applicable methods and tools to decrease the resource requirement and increase efficiency of habitat mapping.

Pressure-impact assessment:

- 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;
- 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:

- Research on links between pelagic and benthic habitats/biotopes and ecosystem functions to better understand the role of benthic and pelagic ecosystem components for ecosystem functioning, to strengthen the ecological relevance of both assessments and measures;
- Development of criteria for estimating the contribution of pelagic and benthic habitats to ecosystem services to evaluate the benefit of healthy habitats to human well-being;
- Analyses of the role of traits for functioning of pelagic and benthic habitats/biotopes, including the link to food webs, with special focus on a changing climate and oxygen depletion, to improve the holistic aspect of assessments and the causal link between pressures, impact and state.

Habitat restoration:

- Identify areas, as well as develop and improve 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.

Box 2. Selection of HELCOM Recommendations that would benefit from the highlighted science needs:	
40/1	CONSERVATION AND PROTECTION OF MARINE AND COASTAL BIOTOPES, HABITATS AND BIOTOPE COMPLEXES CATEGORIZED AS THREATENED ACCORDING TO THE HELCOM RED LISTS
28E/9	DEVELOPMENT OF BROAD-SCALE MARINE SPATIAL PLANNING PRINCIPLES IN THE BALTIC SEA AREA
35/1	SYSTEM OF COASTAL AND MARINE BALTIC SEA PROTECTED AREAS (HELCOM MPAs[1])

1.3 Food webs

Species diversity is known to be low in the Baltic Sea due to its character as a geologically very 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 foodwebfood 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 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 by human activities or indirectly, e.g. by climate change. The Baltic Sea food webs have at present inadequate status and are deteriorating despite management and governance measures (HELCOM 2018). Both upper and lower levels of food webs are relevant to consider when assessing changes in predator-prey interactions as well as the larger scale variations of ecosystem functioning.

To improve management of human activities and the conservation efforts in the Baltic Sea, the necessity of understanding the processes between elements of the food webs are stated in several HELCOM reports and planning documents and are reflected as identified science needs.

Highlighted science needs

Indicators:

- Development of integrated pelagic indicators for assessment of status of planktonic communities, including size spectra, taxonomic diversity and utilizing phyto-and zooplankton data together.

Trophic interactions:

- Better understanding of changes in trophic relationships, age categories and species composition of fish caused by fishery activities;
- Better knowledge on benthic - pelagic coupling and associated food web implications from changes in benthic conditions from e.g. climate change.

Models to support development of measures

- Development of indicators which capture key food-web states and processes which underlie critical and complex ecosystem dynamics, and applying existing food web models including all its compartments fish, mammals and birds for detection of horizontal (plankton-benthos) and vertical (lower levels- upper levels) interactions, and further use in protection/conservation measures.

[1] Former HELCOM BSPAs

1.4 Marine Protected Areas

Well-designed and managed Baltic Sea Marine Protected Areas (HELCOM MPAs) locate where the conservation need is most urgent and where the potential benefit is highest, especially an ecologically coherent network of such areas, is an important tool for fulfilling HELCOM ambitions for a healthy Baltic Sea. Such a network would help potentially improve the resilience of the entire ecosystem to external threats such as eutrophication and climate change by increasing and maintaining biodiversity. Large no-use areas are important aspects of such a network. However, despite large 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 not complete nor does it fulfil the requirements for coherence or 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.

The science needs would contribute directly to the implementation of HELCOM Recommendation 35/1 on System of Coastal and Marine Baltic Sea Protected Areas (HELCOM MPAs[2]).

Highlighted science needs:

Evaluation of spatial protection measures:

- Development of scientific criteria to be used to identify potential no-take zones, with the aim of limiting pressure stemming from fishing efforts and improving the state of biodiversity;
- Quantifying the effectiveness of spatial conservation measures, especially the link between measures and change in state, to help guide conservation efforts;
- 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 of services etc;
- Establishment of criteria to assess the 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

- Establishment of science-based criteria and targets to be used for the HELCOM coherence assessment methodology;
- 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;
- 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 a basis for planning and optimizing the MPA network and ensure coherence in the long term.

[2] Former HELCOM BSPAs.

2. HUMAN DIMENSION

Humans are intractably linked to the Baltic Sea ecosystem through the benefits of its resources and the impacts of human activities on its state. Historic records of cod catches show a viable fishery dating back to 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 circa 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 2018).

Many sources of pollutants are land-based and the Baltic Sea, with its slow water exchange (c. 40-50 years) with the North Sea, large population in the catchment 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 is 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 introduction of non-indigenous species (NIS) through ballast water and release of hazardous substances that are associated to 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 HELCOM has made many agreements to jointly curb and mitigate the impact of human activities on the environment. An example is the large number of joint Recommendations, including for example limit values for release of substances, BAT and BEP guidelines, agreements on spatial restrictions for certain activities, and much more. While some activities and pressures have been studied for a long time in Baltic Sea the recommendations and other HELCOM commitments still need continuous updates based on 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 are still needed.

This chapter focuses on research needs necessary 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 climate changes is central since it will need to be considered in the management of all aspects of the Baltic Sea, including in order to adapt policies and to take measures to mitigate the anticipated long-term changes.

2.1 Climate change

Climate change has, and will have, major impact on the marine environment, from genes to ecosystems, 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. These changes will cause changes in hydrography and circulation in the sea, most likely changes are increased 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 point toward a decrease than an increase, with a potential change in stratification, too. With increasing CO_2 concentration in the atmosphere acidification 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, most probable decreasing, salinity would have drastic effects on species distribution in the brackish part of the Baltic Sea.

Socioeconomic development is occurring concurrently and, in cases, in response to climate change. Results so far show that for eutrophication, the global and regional socioeconomic development can be as important as climate change itself in shaping the future Baltic Sea environment.

The challenges presented by marine climate change are by their nature a regional concern and the topic is cross-cutting, covering aspects from science to high level policy. The aim of HELCOM work on climate change is to increase the resilience of the system of the Baltic Sea with regards to climate change impacts. To achieve this the climate change work within HELCOM focuses on a long-term, multi-disciplinary approach to understanding and communicating the implications of climate change for the marine and coastal environment.

Highlighted science needs

- Further development of regionalized scenarios of climate change effects on the physical environment (hydrography and circulation, sea level, sea ice, morphology) of the Baltic Sea as a basis for both scientific and managerial assessments of the consequences of climate change; coastal building and functioning of harbours should be identified;
- Further development of scenarios that illustrates the impact of multiple global and regional drivers, both socioeconomic development and climate change, on activities and resulting pressure in the Baltic Sea. One example would be, how do changing global food demand together with changed climate influence agriculture in the catchment and the subsequent leakage of nutrients to the sea;
- Development of ways to incorporate climate change aspects to the HELCOM Nutrient Reduction Scheme to ensure that BSAP eutrophication objectives can be reached even under climate change;
- 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;
- Development of ecologically sustainable adaptions to sea level rise and increased occurenceof extreme weather patterns;
- Develop sediment management concepts for coastal areas with the goal to minimize impacts of coastal protection measures against climate change on natural and dynamic systems.

2.2 Eutrophication

The water quality of almost the entire Baltic Sea is severely impaired by eutrophication to a level that has strongly altered the ecosystem and caused significant benthic habitat loss due to the cumulative effect of a century of high anthropogenic nutrient inputs. Despite long-term and partly successful efforts to reduce nutrient inputs, the status has not improved substantially yet and continued reductions of nutrient inputs are needed to reach levels that ensuring that the???? goal of a Baltic Sea unaffected by eutrophication will be reached.

Management of Baltic Sea eutrophication is complicated by the slow response of the system in that it takes decades to demonstrate effects on open sea water quality from implementation of measures. For this purpose HELCOM uses results from models to estimate Maximum Allowable Inputs that are consistent with good environmental status as agreed in HELCOM, and there are several studies available on the combined effect of nutrient input changes and climate change. However, there are also slow responses to measures on diffuse sources on nutrient inputs via rivers that is so far not very well studied on a Baltic Sea scale. Increased knowledge on the effects of climate change on eutrophication processes are needed, both in the catchment area and the sea.

There are still demand for the development and implementation of additional measures to reduce the nutrient inputs from waste water, 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 to cost-effectively improve eutrophication status in the Baltic Sea.

[Reference to HELCOM nutrient reduction scheme to be added]

Highlighted science needs

Input of nutrients:

- 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;
- How eutrophication will directly/indirectly affect the oxygen conditions of the Baltic Sea, i.e. by increasing the area of anoxic bottoms and thereafter causing enhanced internal loading.

Measures to reduce nutrient input:

- Improved understanding and quantification of nutrient sources that leads 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 Baltic Sea countries;
- Development of efficient and environmentally sustainable nutrient recycling techniques;
- Studies on new technical practices to decrease nutrient loading (e.g., gypsum treatment of fields) should be developed;
- Maritime nitrogen emissions to the Baltic Sea should be reduced, for example, by increasing the use of liquefied natural gas (LNG) as ship fuel.

Nutrient recycling process:

- Investigate the obstacles, both natural and societal, preventing the decrease of nutrient concentrations in the sea including improving understanding and modelling of internal biogeochemical transformations and legacy of nutrients in the sea;

- 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;
- Knowledge from social sciences: what kind of attitudes towards nutrient load reduction and other environmental actions exists in various riparian countries of the Baltic Sea?

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 farms, as well as maritime activities. Just a small fraction of the chemicals that are emitted from society are monitored or screened for. Consequently, the chemical cocktail 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 (or groups of 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 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 the chemical pollution.

[Reference to HELCOM agreement/strategy that will benefit from closing the knowledge gap]

Highlighted science needs

Input of hazardous substances:

- Improved knowledge on use patterns and emissions of hazardous substances from various sources, both land-and sea-based, and modelling of relative importance of different transport routes to support 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;
- Retrospective temporal trend analysis of emissions and environmental concentrations, e.g. through historic deposition in sediments or samples in biota banks, to assess efficiency of implemented measures and interactions with multiple pressures and stressors - both legacy contaminants and contaminants of emerging concern;
- Screening of environmental matrices and land and sea-based sources such as wastewater, industries, urban areas, shipping and off-shore activities for contaminants of emerging concern, using both target and non-target analysis, potentially coupled to effect directed analysis and modelling to facilitate identification of emerging threats and function as early warning mechanism;
- Improved knowledge on submerged munition and its integrity (e.g. status of corrosion, leakage of the hazardous substances) per location including risk assessment for marine environment.

Status and effects of contaminants:

- 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;
- Development of methods that can link observed effects with causing agents, i.e. identification of *substances/mixtures* or tracing *human activities* releasing a broad range of contaminants mainly responsible for the observed effects;
- 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;

- Development of risk assessment approach for contaminants from munition (in biota, if applicable sediment and water), and development of environmental) quality standards for assessing the need for remediation.

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. Research in the Baltic started in early 2000s. Studies on the amount, type and distribution of macro- and microlitter are ongoing, including sampling of water, bottom sediments and beach surveys, and common guidelines for beach litter surveys have been compiled. However, due to varying methodologies in water and sediment sampling, sample processing and laboratory analyses applied in different research institutes, the collected data is not fully comparable yet.

HELCOM has adopted a Regional Action Plan on marine litter, which includes the commitment to significantly reduce marine litter by 2025 compared with 2015. However, there are already are a few studies on marine litter in the Baltic region, but due to the relatively short period of monitoring, and therefore, there is not enough reliable data on the scale of the problem and understanding of the most efficient ways of its mitigation, there is still a need of further research. . To reach this goal, fundamental knowledge on the sources of litter as well as on how to sample and assess the presence and impact of litter is still needed.

Highlighted science needs

Indicators and impacts of litter:

- Need for harmonized methodologies (EU and RUS) for monitoring of beach litter, and microplastics in water and in bottom sediments, including field sampling, sample pre-treatment and plastics identification in laboratory. This methodology must be cost-efficient and applicable in all countries, including RUS.

Input and fate of litter:

- Identification and quantification of sources and pathways of macro-, mesolitter and microplastics, including identification identification of the sources at sea and on land;
- Studying fragmentation of macroplastics in the environment to better estimate their role and importance in the formation of secondary microplastics
- Understanding of interactions of environmental conditions and natural factors like currents, winds, bottom topography, river runoff, etc. and their influence of marine litter distribution;
- Measures to reduce the input of litter from land, sea and other sources, like marine traffic:
- Evaluation of effectiveness and adaptation to regional needs of management actions, e.g. bans of plastics, wastewater treatment to remove microplastics, awareness programmes, etc.
- Developing 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.
- Understanding the social attitude to the problem and raising awareness: activities of NGOs and public campaigns like “beach cleans” and other events, environmental education at schools and universities (development of specialized study courses, etc.).

2.5 Underwater noise

Sound propagates effectively in water and various marine animals rely strongly on sound for communication, orientation and prey capture. Also, noise from anthropogenic activities can propagate far from the source and affect communication (masking) and behaviour of animals, and if intense enough, even cause direct damage to hearing and tissue and, in worst case, lead to death, in particular if no mitigation measures are applied. Anthropogenic underwater noise appears as **impulsive** noise from e.g. explosions, seismic surveys, pile driving and sonars or and **continuous** noise sources, from ships and marine infrastructure (oil and gas platforms, offshore wind turbines etc.). At present, significant uncertainties are found regarding both, the pressure on the ecosystem and the impact on it, whereas the uncertainties related to impact are most severe. Assessing impact requires knowledge of how anthropogenic noise affects animals under environmental conditions, knowledge of the actual noise exposure of marine 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 effectivity of mitigation measures as well as the assessment of their potential negative side effects.

Science needs related to impact 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 (currently in draft).

Highlighted science needs

Impact of impulsive noise:

- Expand knowledge of pressures from sources currently not monitored, such as echosounders, sonars, subbottom profilers etc, to support assessment of impact both on small scale (EIAs on specific projects) and large scale (sub-basin scale);
- Explore long-term consequences of noise exposure to individuals and populations (see also Species section);
- Develop or adapt impact indicator(s) for impulsive noise and assessment methods for impulsive noise applicable to the Baltic Sea, taking into consideration work done in TG-Noise.

Impact of continuous low frequency noise:

- Improvement of methods for long-term acoustic monitoring, including modelling in shallow waters, taking into consideration work done in TG-Noise;
- Develop or adapt methods to include contributions from smaller, recreational vessels and static sources in modelling, taking into consideration work done in TG-Noise;
- Expand knowledge of metabolic and physiological consequences of disturbances caused by vessel noise;
- Expand knowledge of the impact of continuous low frequency noise (see Species section);
- Develop or adapt impact indicator(s) for continuous low frequency noise to the Baltic Sea as required by the EU Marine Strategy Framework Directive and as tool for the regional assessment (HOLAS);

- Encourage 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:

- Develop or adapt effective noise abatement methods applicable to underwater explosions and/or alternatives to detonation;
- Develop and test technical and operational measures to reduce impact from other impulsive sources.
- Evaluation and feasibility assessment of Best available Technique (BAT) for underwater noise reduction (e.g. silent ships)
- Evaluation and feasibility assessment of Best Environmental Practice (BEP) for underwater noise reduction (re-routing, slow steaming, etc.)

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 impossible to eradicate after they have established themselves in the ecosystem. The shallow and enclosed nature of the Baltic Sea, low salinity and the intense marine traffic makes the Baltic Sea 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 ship hulls and harbors and ports are therefore hot spots for the introduction of non-indigenous species. 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 iwis focused on the general needs to improve knowledge for the purpose of assessing the introduction and status of NIS and the impacts of NIS on other ecosystem components.

Highlighted science needs

Assessment of NIS:

- Development of reliable species identification methods, including molecular methods such as eDNA and developing DNA barcodes for Baltic Sea NIS, which would improve monitoring efforts;
- Development of a regionally harmonized indicator for abundance and spatial distribution of established NIS (MSFD D2C2) and associated threshold values;
- Development of an indicator for NIS with regard to environmental impact; ecosystem services, health and socioeconomic aspects, which will allow e.g. early warning of risks associated with them;

Impacts of NIS:

- Better understanding of the effects of small NIS taxa such as protozoa, bacteria, and viruses. They remain unrecognized, undetected and they have no priority in surveying NIS, and knowledge on their impact is thus limited.
- Development of methodologies to quantify the impact of NIS on the ecosystem functioning, including for communities, biological process and habitats, and on its carrying capacity and resilience. Improved knowledge would support the development of an indicator on adverse effects by NIS.

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.

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 Special Area under MARPOL Annexes I, II, IV and V and Sulphur and 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. In case of 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:

- Quantification of hazardous substances like PAHs and heavy metals from discharge water from Exhaust Gas Cleaning Systems (EGCS) to assess the need for more stringent regulation;
- Tools for real-time information and smart monitoring of underwater noise emission;
- High resolution data on shipping activities for cumulative impact assessment;
- Quantification of the amount of oil released to 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.
- Evaluation of effects and consequences of sewage discharges from cargo vessels;
- Evaluation and estimation of volumes of discharges of harmful cargo residues into the Baltic Sea;
- Research on impact and management of food waste from ships in the Baltic Sea;
- Evaluation of effects on the marine environment of discharge water from Exhaust Gas Cleaning Systems (EGCS).

Development of measures to reduce pressures from shipping:

- Development of technical- and management options and evaluation of impacts of grey water discharges from vessels, in particular from passenger and cruise ships;
- Identification and feasibility assessment of Best available Technique (BAT) and Best Environmental Practice (BEP) for underwater noise reduction;
- Contribute to the research and development activities in the context of the IMO´s initial GHG strategy;
- 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:

- Research on indicative sampling of ballast water for BWMC D-2 compliance monitoring in the context of the IMO BWM EBP;

- Future needs of oil combatting capacity should be mapped and operational functionality of oil-combatting operations should be ensured regardless of season
- Further analysis and consideration of the human factor in the maritime traffic risk forecasting system to make it more reliable;
- 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, gillnets-fisheries risk bycatch, including endangered species, and bottom trawling causes disturbance to sensitive benthic habitats. A great proportion of the fleet in the Baltic Sea consists of small-scale fisheries. There is currently too few data available in order to quantitatively assess resulting impacts of fisheries in the Baltic Sea. An advanced reporting as well as research on fisheries impacts and mitigation measures is needed to improve fisheries management that together with other environmental factors impact fish stocks enables reaching a good status of habitats and species and achieving ecologically sustainable fisheries.

[Mention as relevant specific HELCOM agreement/strategies that are relevant of this section.]

Highlighted science needs

Enhanced mapping of fishing impacts:

- Intensified research on bycaught species of all métiers to assess bycatch rates of seabirds, marine mammals and protected fish species;
- Applied research on alternative methods for assessing and managing commercial fish stocks for their sustainable use;
- 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.

Advancement of bycatch mitigation measures:

- Intensified research on bycaught species of all métiers in order to advance bycatch mitigation measures;
- Development and testing 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:

- Analysis of the recovery process of benthic habitats and species in areas closed for fishing to assess management effectiveness;
- Calculation/modelling of socio-economic aspects of fisheries affecting benthic habitats and fisheries management options throughout different métiers, performance of cost-benefit analyses;
- 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. For the sake of this document these topics have been presented separately, in reality they are all linked and successful management requires 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 into management, including humans, 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 on the benefits in terms of ecosystem services and revenues from economic sectors. The implementation of EA and EBM furthermore require 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 integrated character are also represented under the other chapters, for example Food webs and Climate change.

3.1 Ecosystem approach

HELCOM and OSPAR agreed on the following common definition of the ecosystem approach for their convention areas at their Joint Ministerial Meeting 2003 in Bremen, Germany: *"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 is advanced on the Baltic Sea level through the implementation of the Baltic Sea Action Plan.

Although the ecosystem approach 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.

Highlighted science needs:

- Evaluation of in what way and how far the ecosystem approach, i.e. the management of human activities in the Baltic Sea Region has been implemented;
- Establishing rules of procedure and approaches for implementation of the precautionary principle in the Ecosystem Approach, ensuring compatibility with other assessments;
- Investigate how the provisions of the Paris Agreement, as response to the threat of climate change, can be incorporated into the ecosystem approach concept for the Baltic Sea;
- Evaluation of approaches, measures and instruments to improve the state of the Baltic Sea towards good environmental status through application of the ecosystem approach.
- How could Decision Support tools be used in management of activities in the Baltic Sea area and must existing tools be revised or are new developments necessary.

3.2 Maritime Spatial Planning

In 2010, the ecosystem approach was incorporated into 10 common HELCOM and VASAB Maritime Spatial Planning (MSP) principles, where it 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 ecosystem approach in MSP has been further developed through joint regional projects (e.g. Baltic SCOPE 2015-2017 and Pan Baltic SCOPE 2018-2019).

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

Highlighted science needs

- Identify an appropriate collection of transparent spatial planning tools for a comprehensive consideration of ecosystem components;
- Investigate how Maritime Spatial Planning, applying the guiding principles of the ecosystem approach, 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;
- Establish processes with an ultimate goal of a comprehensive marine, ecosystem-oriented planning for the Baltic Sea area;
- Develop guidance to the application of ecosystem-based approach in MSP to protect biotopes of high ecological value and sensitivity;
- Develop a common methodology for indicating areas of high natural value, as a basis for steering harmful activities away from such areas.

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 be 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 impacts assessments can be used as a tool for implementing holistic environmental management (EBM) to support sustainable development e.g. to 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 providing 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, prioritising 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.

HELCOM Ministers agreed in their Brussels Ministerial Declaration 2018 to improve the understanding of impacts of human activities, 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.

Highlighted science needs

- Improve spatial modelling to enable improved resolution of the pressure and impact maps, thus increasing their usability for management;
- Develop a reliable method for validation of the results of a pressure or impact assessment to improve the confidence of the assessments and by extension their applicability in management;
- Improved understanding of the sensitivity of ecosystem components to various pressure, thus strengthening the link between pressure and change in state to support assessment, management actions and the setting of realistic conservation targets;
- Improved understanding of the accumulation and synergistic or antagonistic effect of several pressure overlapping in space and time, to better guide management measures and provide context to results of other assessments.

3.4 Economic and social analyses

Economic and social analyses are needed to fully apply ecosystem-based approach 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 economic and social system, 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 (Müller et al., 2015) and therefore is used as a tool in the economic and social analyses. Identification and valuation of ecosystem services provides an option to quantify the impacts of ecosystems on human welfare, find the gaps and contribute to 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 the HELCOM decisions such as the Ministerial Declaration 2018 the Roadmap for HELCOM work on economic and social analyses.

Highlighted science needs

- Better understanding 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;
- Evaluation of the costs, effects and benefits of measures and policies to support the development of effective new measures and policies (e.g. BSAP);
- 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. BSAP);
- Development of approaches and assessments integrated with marine ecosystem services;
- Development of quantitative criteria to describe ecosystem services to improve knowledge on the extent of ecosystem services in the Baltic Sea and their changes;
- 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.

4 How the HELCOM Science Agenda can be implemented

Direct involvement of HELCOM

HELCOM has some possibilities for direct involvement in science-based projects through external funding mechanisms. HELCOM can for example act as 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. On a number of occasions HELCOM has furthermore acted as partner in regionally coordinated projects that have been financed through EU Interreg programmes. In the case of carrying out joint assessments or 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 for development of applications with HELCOM as coordinator or partners. The possibilities for HELCOM to be directly involved in science projects is however limited in terms of possibility to apply, administer and coordinate projects. Thus, the main part of the knowledge enhancing activities takes place in the scientific institutions and universities in the HELCOM countries.

Main initiatives to spread information from Science Agenda

Since the implementation of the major part of the Science Agenda will depend on external funding resources and participation of the experts from the Member countries, it is foremost a way of communicating HELCOM science needs to the 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,
    - organisations 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 be 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 the scientific knowledge and understanding into effective actions to support a sustainable development. In Annex 2 to this report the links between the highlighted knowledge and research to 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 Baltic Sea Action Plan and 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 scientist from several Baltic Sea countries the opportunity to work together already in the formulation phase of projects, 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', develops 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 can likely support part of the HELCOM Science Agenda, in particular the more research demanding knowledge needs while some of the more applied and short-term knowledge needs are less likely to fit the scope and criteria of the envisioned BANOS research program. *[By time of approval of the Science Agenda more information may be available on the tentative start of such programme*]. 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.

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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.

- EN Benthic (benthic species and habitats),
- EN ESA (economic and social aspects), prepared by the chair, Finland, Estonia, Latvia, Lithuania and Germany,
- JWG Birds, prepared by the chair and with input from Germany and Sweden,
- EN Noise, prepared by the chair, based on the implementation of the draft HELCOM roadmap on underwater noise,
- EG MAMA (mammals),
- RedCore/PLC (input of nutrients),
- EN Hazardous substances,
- IN EUTRO (eutrophication),
- FISH-PRO project (coastal fish).
- 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)
- link to HELCOM agreements and activities
- links to the DPSIR concept
- link the UN Decade of Ocean Science and UN Sustainable development goals

The aim is to provide more information to scientist 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 example mapping:

D(A)PSIR:

The term "Activities (A)" has been added to the DPSIR scheme as it is a relevant aspect for purpose of HELCOM work while underlying "Drivers" are more rarely addressed. The designations in the tables is linked to the type of knowledge/research while in a broader sense the knowledge needs may be linked to additional aspects of the DPSIR 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)
R=Response (measures, adaption to changes, here also including development, implementation and evaluation of management tools)

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 defined i.e.:

- 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 SDG targets

Full list be found at https://www.un.org/sustainabledevelopment/sustainable-development-goals/

Species

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Better knowledge of species distribution, population sizes and ecology, and habitat selection to support precise status assessments and how to best direct management measures;	Mapping, species attributes	Rec 17/2 (Harbour Porpoise Rec 27/28-2 (Seals) Rec 34E/1 (Bird Habitats Rec 37/2 (threatened species)	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2,14.5
Development of status indicators for coastal fish communities, including size and age aspects of populations and distributional range of species; for bird populations considering the reproductive success; for marine mammals considering abundance and distribution for harbour porpoise and health related indicators for seals, as well as Environmental Quality Standards (EQS) for relevant hazardous substances regarding marine mammals.	Indicators, status	Indicator development	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
Research on impact of noise on marine mammals, fish populations and benthic communities;	Impacts on status	Indicator development	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
Research on impact of macrolitter and microplastics on species and communities;	Impacts on status	Indicator development	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
Better knowledge and understanding of the needs for development of effective species conservation plans, in particular for marine mammal, bird and fish populations;	Measures, development	Rec 37/2 (threatened species)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development of approaches on how to quantify the effectiveness of specific conservation measures for species;	Measures, evaluation	Rec 37/2 (threatened species)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Research on definition of precautionary approach levels for seals in their management units.	Threshold value for conservation	Rec 27/28-2 (Seals)	S, R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Habitats

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Regionally coordinated mapping of habitats/biotopes, considering MSFD, Habitats Directive and HELCOM Red List to guide scientific surveys, facilitate data exchange and support national reporting;	Mapping, habitats	Rec 40/1 (threatened habitats)	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Detailed mapping of substrates, communities and pressures for further elaboration of sensitive areas and conflict areas and to steer Maritime Spatial Planning.	Mapping, habitat attributes and pressures	Rec 40/1 (threatened habitats)	P, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
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 on status	MD 2018 (CHECK formulation) Rec 40/1 (threatened habitats)	P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Analysis of age and/or size distribution of long-lived species to indicate where pressures adversely affect benthic communities.	Species attributes (indicator of status?)	Indicator development	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Assessment of links between benthic habitats/biotopes and ecosystem functions to better understand the role of ecosystem components for ecosystem functioning;	Ecosystem interactions	Rec 40/1 (threatened habitats)	S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development of criteria for estimating the contribution of benthic habitats to ecosystem services to provide evidence that healthy ecosystems benefit human well-being;	Ecosystem services	MD 2018, Contribution to ESA developments	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Analysis of traits of benthic habitats/biotopes and food webs in a changing climate and under oxygen depletion.	?		S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Develop methods for the restoration of seagrass beds and reefs	Measures, development	Rec 40/1 (threatened habitats)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Identify areas and methods for the restoration of benthic habitats/biotopes, e.g. habitat-forming species such as seagrass beds and reefs, to support nature based-solutions for tackling climate change.	Measures, development	Rec 40/1 (threatened habitats)	R	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.

Food webs

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Development of integrated pelagic indicators for assessment of status of planktonic communities, including size spectra, taxonomic diversity and utilizing phyto-and zooplankton data together.	Indicators, status		S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Better understanding of changes in trophic relationships, age categories and species composition of fish caused by fishery activities is needed;	Impacts, fisheries		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.
Better knowledge on benthic - pelagic coupling and associated food web implications from changes in benthic conditions from e.g. climate change.	Impacts, interactions		P, S, S/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
Development and applying existing food web models including all its compartments including fish, mammals and birds for detection of horizontal (plankton-benthos) and vertical (lower levels- upper levels) interactions, and further use in protection/conservation measures.	Models		S, R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Marine protected areas

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
What scientific criteria should be used to identify areas, based on a scientific qualification as no-take zones?	Method development, measures	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
How can the effectiveness of spatial conservation measures be quantified?	Method development, measures	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
What scientific tools are adequate for a regular assessment of the effectiveness of spatial protection measures?	Method development, evaluation of measures	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5

What criteria are appropriate to assess management effectiveness in single MPAs and the network as a whole, respectively?	Method development, evaluation of measures	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
Which science-based criteria and targets should be used for the HELCOM coherence assessment methodology?	Method development, assessment	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
What parameters justify designation/expansion of MPAs in order to achieve coherence of the MPA network also in relation to climate change?	Measures, development	Rec 35/1 (MPAs)	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5
Map/model benthic habitats/biotopes and species distribution maps for different climate change scenarios		Rec 40/1 (threatened habitats)	I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.5

Climate changes

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Further development of high-quality regionalized projections of climate change effects on the physical environment (hydrodynamics, sea level, sea ice, morphology) of the Baltic Sea as a basis for both scientific and managerial assessments of the consequences of climate change	Scenario development, climate change		P	A predicted ocean where society understands and can respond to changing ocean conditions	13,2, 14.3
Further development of scenarios that relates to global change drivers impacts activities; and quantifies the effects on pressures on the Baltic Sea. For example, how changed combined changing global food demand together with changed climate influence agriculture in the catchment and the subsequent nutrient load to the sea;	Scenario development, cumulative pressures		P	A predicted ocean where society understands and can respond to changing ocean conditions	13,2, 14.3
Development of ways to incorporate climate change aspects to the HELCOM Nutrient Reduction Scheme to ensure that BSAP eutrophication objectives can be reached even under climate change;	Adaptation of policy		R	A predicted ocean where society understands and can respond to changing ocean conditions	13.2, 14.3
Regional effects of climate change induced water temperature increase, oxygen decline, sea level rise and changes in pH on biota, biodiversity and ecosystem functioning should be assessed;	Impacts on status		P, S/I	A predicted ocean where society understands and can respond to changing ocean conditions	14.3
Risk assessment of species shifts in relation to climate change induced changes in habitats in the Baltic Sea should be conducted.	Risk assessment		P	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	14.3

Development of ecologically sustainable adaptions to sea level rise and increase of extreme weather patterns	Measures, adaptation to change		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed A safe ocean where life and livelihoods are protected from ocean-related hazards	13,2, 14.3
Develop sediment management concepts for coastal areas with the goal to minimize impacts of coastal protection measures against climate change on natural and dynamic systems	Measures development, adaptation to change		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed A safe ocean where life and livelihoods are protected from ocean-related hazards	13,2, 14.3
Investigate the impact of climate change on protected areas in the coastal zones and identify possible spatial shifts of habitats	Impact on habitats		P, S/I	A predicted ocean where society understands and can respond to changing ocean conditions	14.3

Eutrophication

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Improved and harmonized catchment modelling to determine the sources of nutrient inputs and to quantify the anthropogenic sources versus the natural background is imperative to determine appropriate measures to reduce the total nutrient inputs to the Baltic Sea basins by cross-country cooperation.	Models, input of nutrients	MAI/CART	P	A clean ocean where sources of pollution are identified and reduced or removed	14.1
Improved understanding and quantification of nutrient sources that leads 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 Baltic Sea countries;	Activity-pressure links	MAI/CART	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
Develop efficient and environmentally sustainable nutrient recycling techniques	Measures, development		R	A clean ocean where sources of pollution are identified and reduced or removed	14.1
Investigate the obstacles, both natural and societal, preventing the decrease of nutrient concentrations in the sea including improving understanding and modelling of internal biogeochemical transformations and legacy of nutrients in the sea;	Models, hinders for improvement	MAI/CART	P, S/I, R	A clean ocean where sources of pollution are identified and reduced or removed	14.1
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, development of	Models, ecosystem interactions	MAI/CART	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	14.1

harmonized indicators, and understanding and modelling of interactions between the coast and the open Baltic Sea;					
Knowledge from social sciences: what kind of attitudes towards nutrient load reduction and other environmental actions exists in various riparian countries of the Baltic Sea?	Human perception of eutrophication		(I)*	A clean ocean where sources of pollution are identified and reduced or removed	14.1

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

Hazardous substances

Highlighted knowledge needs	**Type**	**Implementation of**	**DPSIR**	**UN Decade of Ocean Science**	**UN SDG**
Improved knowledge on use patterns and emissions of hazardous substances from various sources, both land-and sea-based, and modelling of relative importance of different transport routes to support 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, input of pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Retrospective temporal trend analysis of emissions and environmental concentrations to assess efficiency of implemented measures and interactions with multiple pressures and stressors - both legacy contaminants and contaminants of emerging concern;	Level of pressures		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Screening of environmental matrices and land and sea-based sources such as wastewater, industries, urban areas, shipping and off-shore activities for contaminants of emerging concern, using both target and non-target analysis, potentially coupled to effect directed analysis and modelling to facilitate identification of emerging threats and function as early warning mechanism.	Models, input of pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Improved knowledge on submerged munition and its integrity (e.g. status of corrosion, leakage of the hazardous substances) per location including risk assessment for marine environment.	Mapping, risk assessment		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Development and harmonization of monitoring methods based on biological effects that capture impact of the total chemical mixture in the marine environment (e.g. specific bioassays related to the respective mode of action of the chemicals) and can function as an early warning leading to further assessment of substances (screening for the substances which are giving the signal in the bioassay test)	Impact on biota, method development		S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4

or activities releasing a broad range of contaminants mainly responsible for the effects;					
Research on transport and transformation 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,		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
Development of monitoring system for contaminants from munition in biota, if applicable sediment and water, Deriving of environmental quality standards for assessing need for remediation	Method development		P, S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4

Marine litter

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Need for harmonized methodology (EU and RUS) for monitoring of beach litter, and microplastics in water and in bottom sediments.	Method development	Rec 36/1 (marine litter)	S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 12, 5
Identification and quantification of sources and pathways of macrolitter and microplastics;	Input of pressure	Rec 36/1 (marine litter)	P	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 12, 5
Degradation of different type of plastics, including degradation from macro- to microplastics;	Transformation of pressure	Rec 36/1 (marine litter)	S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 12, 5
Measures to reduce the input of litter;	Measures, development	Rec 36/1 (marine litter)	R	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 12, 5
Evaluation of effectiveness and adaptation to regional needs of management actions e.g. bans of plastics, wastewater treatment to remove microplastics, awareness programmes etc.	Measures, evaluation	Rec 36/1 (marine litter)	R	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 12, 5

Underwater noise

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
				A clean ocean where sources of pollution are identified and reduced or removed	14.2
				A clean ocean where sources of pollution are identified and reduced or removed	14.2

Non-indigenous species

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Improved monitoring of NIS in natural areas as well as hot spot areas not properly covered by monitoring yet such as coastal hard bottoms (sessile and mobile epifauna) and marinas;	Monitoring		S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development of reliable species identification methods, including molecular methods;	Methods development, species identification		P; S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Identify changes in communities, biological processes and habitats caused by NIS;	Monitoring		S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development of a NIS impact indicator (MSFD D2C2) and associated threshold values;	Indicator status		P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development of a regional harmonised indicator for NIS with regard to environmental impact; ecosystem services, health and socioeconomic aspects, which will allow e.g. early warning of risks associated with them;	Indicator status		P, S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Research on the use of eDNA methods for NIS monitoring and risk assessments.	Methods development, species identification		P; S/I	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Shipping

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Quantification of hazardous substances like PAHs and heavy metals from scrubber discharge;	Level of pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Tools for real-time information and smart monitoring of underwater noise emission;	Level of pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	14.2
High resolution data on shipping activities for cumulative impact assessment;	Activity, spatial distribution		A	A clean ocean where sources of pollution are identified and reduced or removed	
Quantification of the amount of oil released to the Baltic Sea from small but continuous emissions of mineral oils and assessment of the environmental effects.	Level of pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	12.4
Evaluation of effects and consequences of sewage discharges from cargo vessels;	Impacts		P, S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 14.1
Research on impact and management of food waste from ships in the Baltic Sea;	Impacts		P, S/I	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 14.1

Technical- and management options and impacts of grey water discharges from cargo vessels;	Impacts, Measures		S/I, R	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 14.1
Evaluation of effects of scrubber wash water from open loop and hybrid systems;	Measures, evaluation		R	A clean ocean where sources of pollution are identified and reduced or removed	12.4, 14.1
Identification and feasibility assessment of Best available Technique (BAT) and Best Environmental Practice (BEP) for underwater noise reduction;	Measures		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Contribute to the research and development activities in the context of the IMO´s initial GHG strategy;	Pressure		P	A clean ocean where sources of pollution are identified and reduced or removed	9.4, 12.4, 14.1
Development of risk assessment and standards with respect to in-water cleaning (IWC) of commercial ships and leisure boats.	Risk assessment, IWC		P	A clean ocean where sources of pollution are identified and reduced or removed	14.2, 14c
Research on indicative sampling of ballast water for BWMC D-2 compliance monitoring in the context of the IMO BWM EBP;	Methods development, pressure		P	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14c
Further analysis and consideration of the human factor in the maritime traffic risk forecasting system to make it more reliable;				A safe ocean where life and livelihoods are protected from ocean-related hazards	
Research on the importance of electronic failures, human-machine interaction, and the autonomous ship concept.				A safe ocean where life and livelihoods are protected from ocean-related hazards	

Fisheries

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
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	Roadmap on fisheries data	A, P	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
Applied research on alternative methods for assessing and managing commercial fish stocks for their sustainable use;	Management, methods development		P, S/I, R	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
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		S/I, R	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

Intensified research on bycaught species of all métiers in order to advance bycatch mitigation measures;	Mapping Measures, evaluation	Roadmap on fisheries data	P, R	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
Development and testing of new technical measures, alternative gear and modifications to existing gear to decrease bycatch of seabirds, marine mammals and protected fish species.	Measures, development		R	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
Analysis of the recovery process of benthic habitats and species in areas closed for fishing to assess management effectiveness;	Measures, evaluation	HELCOM Rec 35/1	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2, 14.4
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		I	A productive ocean supporting sustainable food supply and a sustainable ocean economy	14.2, 14.4
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	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Ecosystem approach

Highlighted knowledge needs	**Type**	**Implementation of**	**DPSIR**	**UN Decade of Ocean Science**	**UN SDG**
Evaluation of how far has the ecosystem approach in the Baltic Sea Region has been implemented	Management, evaluation		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Establishing rules of procedure and approaches for implementation of the precautionary principle in the Ecosystem Approach, ensuring compatibility with other assessments	Management, implementation		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Investigating how the provisions of the Paris Agreement be incorporated into the ecosystem approach concept for the Baltic Sea;				A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Evaluating approaches, measures and instruments to improve the state of ecosystems in the Baltic Sea (through e.g. renaturation)	Management tools, evaluation		R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Maritime Spatial Planning

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Identify an appropriate collection of transparent spatial planning tools for a comprehensive consideration of ecosystem components.	Management tools	MSP roadmap	R	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Investigate how Maritime Spatial Planning, applying the guiding principles of the ecosystem approach, 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		A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Establish a processes with an ultimate goal of a comprehensive marine, ecosystem-oriented planning for the Baltic Sea area.	?	MSP roadmap		A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Develop guidance to the application of ecosystem-based approach in MSP to protect biotopes of high ecological value and sensitivity;	Protection of biotopes, management guidance	MSP roadmap			
Develop a common methodology for indicating areas of high natural value (as a basis for steering harmful activities away from such areas);	Identification of high natural values, management tool	MSP roadmap			

Cumulative impacts

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG

Economic and social analyses

Highlighted knowledge needs	Type	Implementation of	DPSIR	UN Decade of Ocean Science	UN SDG
Better understanding 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	A, S	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2

Evaluation of the costs, effects and benefits of measures and policies to support the development of effective new measures and policies (e.g. BSAP)	Evaluation of measures	ESA Roadmap, BSAP	R	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
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. BSAP);	Link status-ecosystem services	ESA Roadmap	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
Development of approaches and assessments integrated with marine ecosystem services;	Methods development, ecosystem services	ESA Roadmap	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
Development 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	(I)*	A healthy and resilient ocean where marine ecosystems are understood, protected, restored and managed	14.2
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	(I)*	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.