Document title	Progress on the HELCOM Science Agenda
Code	4-8
Category	CMNT
Agenda Item	4 - Update of the Baltic Sea Action Plan
Submission date	19.5.2020
Submitted by	Executive Secretary
Reference	

Background

HELCOM 40-2019 agreed to develop a HELCOM Science Agenda, concomitantly with the update of the Baltic Sea Action Plan (Outcome, para 2.29). The agenda is to outline existing and foreseen HELCOM regional knowledge and science needs and will serve the development of activities in HELCOM as well as to inform external funding mechanisms on the research needs of HELCOM.

The HELCOM Science Agenda Task Group was established to prepare the HELCOM Science Agenda based on the contributions received through a survey among HELCOM subsidiary bodies and the tasks assigned by HELCOM HOD 56-2019 (document 2-6, HOD 56-2019).

HELCOM 41-2020 provided guidance to the further development of the Science Agenda based on a proposal prepared by the Science Agenda Task Group (document 4-3, HELCOM 41-2020).

This document includes the guidance for the drafting of texts that has been prepared by the Science Agenda Task Group and Attachment 1 includes the first consolidated draft of the Science Agenda report. The report is to be finalized by end of 2020. During the 3rd meeting the Task Group agreed on some additional steps and common guidance for harmonizing the presentation of science needs that have not been implemented yet (Science Agenda TG 3-2020). The selection and formulation of highlighted science needs is also still ongoing. The report thus provides an insight to the direction of work but is not at a stage for detailed commenting.

Action requested

The Meeting is invited to:

- take note of the ongoing work
- consider the draft report and guide the further direction of work.

Working mode for the Science Agenda Task Group

The Science Agenda Task Group has held three meetings (Science Agenda TG 1-2020, TG 2-2020, TG 3-2020) and one intersessional meeting to follow-up on HELCOM 41-2020. The Group currently consists of representatives of eight countries. The Group has agreed jointly on the outline of the report and prepared guidance on how the texts should be developed. Lead countries have been assigned to drafting of texts for specific topics (Table 1). The list of topics to be addressed in the report has been somewhat shortened based on the advice given by HELCOM 41-2020 and currently consists of fifteen topics covering different aspects of biodiversity, human pressures and activities, and overarching approaches (see list of content in Attachment 1). The drafting is carried out by representatives of the Task Group or by national expertise involved in HELCOM work.

As outlined in the guidance for the drafting of texts (see below) the highlighted science needs primarily draws from the survey of HELCOM knowledge and science needs that was conducted among HELCOM expert networks and Working Groups in 2019. The Task Group also complements the survey results as seen necessary to provide a comprehensive overview of HELCOM knowledge needs, in accordance with the mandate of the Group (document 2-6, HOD 56-2019). Currently first draft texts are available for all but two topics: Underwater noise (Finland has agreed to take the lead) and Cumulative impacts (no lead country).

The survey as a whole will also be made available as supplementary material to the Science Agenda. In order to enhance the survey results, e.g. to reduce overlaps and unclarities, the contributors to the HELCOM survey will be requested to amend the proposals as found appropriate. This request will be made at a later stage, likely in autumn 2020, when the work of the Task Group is more advanced and need for revisions have been further identified.

Outline of the HELCOM Science Agenda

As presented to HELCOM 41-2020, the HELCOM Science Agenda is proposed to be outlined as below. At the 3rd meeting of the Task Group it was furthermore agreed to add introductory texts to the main chapters (Biodiversity, Human dimension, Holistic approaches). Such texts could focus on environmental problems and describe characteristics of Baltic Sea spices and habitats in general. With this approach the introductory text to the individual topics will focus more on how HELCOM addresses these problems and protection of the ecosystem. This change will be implemented at a later stage.

Outline:

1) Introduction;
   - Purpose (why is HELCOM developing a science agenda, who is the target audience)
   - Process (who participated, how were the priority areas identified)

2) HELCOM science needs
   a. Biodiversity
      i. Priorty topic 1, highlights
      ii. Priority topic 2, highlight
      iii. ....
   b. Human dimension
      i. Priority topic 1, highlights
      ii. Priority topic 2, highlights
      iii. ....
   c. Holistic approaches
      i. Priority topic 1, highlights
      ii. Priority topic 2, highlights
      iii. ....

3) How the science agenda can be implemented
   - A reflection on external processes that could support the implementation of the science agenda

Annexes
- Mapping type of research needs vs priority topic
- Specification of highlights, e.g. providing links to HELCOM agreements and activities, providing links to DPSIR concept

Supplementary material
- Survey results

Guidance for prepared draft text for topics

as of Science Agenda TG 3-2020, 30 April 2020.

What to include under a topic:

- each priority topic is briefly described in terms of why it is a priority topic as well as to mention science needs in broader terms. Links to key HELCOM strategies on the topic could be mentioned.
- the general text is followed by more specific 'highlights', drawing from the survey of knowledge and science needs but summarizing and merging proposals from the contributions as suitable. The Science Agenda TG can also complement the survey but additions should be discussed jointly by the Group.
    - 3-8 highlights could be identified for each priority topic.
    - formulate highlighted science needs as stated science needs
    - as needed, clarify the identified knowledge needs and how it will be used (better to use a few extra words than for the reader not to understand the required knowledge or purpose)
    - sub-titles to the highlights can be used to structure different type of knowledge and science needs; to be agreed on a case by case basis
    - recall that texts in the main part of the science agenda should have a relatively long shelf-life (10 years) while specific examples can be given in the annexes which are planned to be updated more frequently.
    - highlights should be formulated as knowledge/research needs (i.e. not as actions e.g. "assess", "monitor").
- maximum space for a priority topic is 1 page, in layout format for printing. Number of words for introductory text to the topic should be kept between 175-225 words.

How to select highlights:

- Focus on identified applied knowledge needs for management of the marine environment
- Focus on proposals with a clear link to the implementation of HELCOM agreement and strategies
- Focus on knowledge needs from a regional perspective

What to address under Biodiversity vs Human dimension:

- Sections on Species, Habitats and Food webs to focus on e.g. interactions between species, habitats, and their abiotic and biotic environment, biological impacts of pressures and activities, knowledge to support development of indicators and status assessment, direct measures to improve species and habitats (e.g. restoration, reintroduction).
- Sections on pressures and activities (Human dimension) to focus on e.g. knowledge to assess status of pressures and distribution/extent of activities, input and sources of pressures, knowledge needed to develop measures to reduce pressures and to evaluate effectiveness of measures.

Table 1. Lead countries for the drafting of texts for the Science Agenda as of 13 May 2020.

Section/Topics	**Lead, Co-lead**
Introduction	ALL; Secretariat first draft
1. Biodiversity	
1.1 Species	Latvia
1.2 Habitats	Germany
1.3 Foodwebs	Latvia
1.4 Marine Protected Areas	Germany
2. Human dimension	
2.1 Climate change	Sweden
2.2 Eutrophication	Sweden, Russia, Finland
2.3 Hazardous substances	Finland, Sweden
2.4 Marine Litter	Russia, Finland
2.5 Underwater noise	Finland, Germany
2.6 Non Indigenous Species	[Poland*], Finland
2.7 Shipping	Germany
2.8 Fisheries	Germany
2.9 Cumulative effects	NO LEAD
3. Holistic approaches	
3.1 ESA	Latvia
3.2 Ecosystem approach	Germany
4. Financing possibilities	ALL; Secretariat first draft
Annexes	Secretariat, ALL

*Poland has prepared a first draft on the topic but does no longer have a representative in the Science Agenda Task Group.

Attachment 1. First consolidated draft of HELCOM Science Agenda

Note: This document is distributed to HELCOM 58-2020 to be informed on the progress of work. All texts are undergoing revisions and the selection and formulation of highlighted science needs are still ongoing. The Science Agenda is to be finalized by end of 2020.

Contents

0. Introduction

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

Commented [X1]: Text to be developed but placed outside the main text (e.g. backside pdf print out)

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 work such as 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 assessment of 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 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 agreements are science-based and builds on the involvement of national expertise, HELCOM is not a scientific body per se and largely depends on advice from the wider scientific community. The main aim of the agenda is therefore to communicate HELCOM science needs to external funding agencies, and to inform and inspire scientists to direct their interest and apply for funds towards meeting the knowledge needs in HELCOM. 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 and to 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).

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 as seen necessary to implement HELCOM

agreements in their respective area of work (Annex 1). This survey generated [200 contributions] that are collated as supplementary material to this report.

A Task Group with national representatives was established to prepare a consolidated Science Agenda. 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. The chapter on 'Biodiversity' presents the science 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 the status. 'Human dimension' describes science needs related to activities and 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. 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~~addressed 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]

Commented [X2]: Not implemented yet. Need a procedure for how to identify "low hanging fruits"

1. BIODIVERSITY

[Brief introductory text for the chapter]

Commented [X3]: To be developed at a later stage

1.1 Species

Species from all compartments of flora and fauna in the Baltic Sea have been impacted by human-induced changes in the ecosystem. HELCOM Red List of the Baltic Sea (2013) contains 145 species as red-listed having various levels of threat status. While several well-targeted measures have been applied and status improved for numerous species, there are still groups at risk of extinction or having unfavourable conditions. Baltic Sea populations are disturbed by noise, habitat deterioration via physical disturbance, contaminants and eutrophication, as well as presence of non-indigenous species. Various kinds of bycatch, hunting and fishing are main causes of mortality of marine animals. Awareness is 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. Therefore, additional investigation effort is needed for development of streamlined protection and conservation measures.

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 seal, harbour porpoise and birds.

Commented [X4]: The relevant recommendations will be listed with the view of e.g. preparing a table. They are too many to list in the text. A similar approach could be taken for other topics with many relevant agreement documents.

Highlighted science needs:

Species mapping

- Better knowledge of species distribution, population sizes and ecology, and habitat selection for precise assessments and improved management measures;

Indicators and impact of pressures

- Development of 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.
- Research on impact of noise on marine mammals, fish populations and benthic communities;
- Research on impact of macrolitter and microplastics;
- Evaluation of population level impacts of bycatch of threatened and declining species;

Conservation plans

- Better knowledge and understanding of the needs 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 on definition of precautionary approach levels for seals in their management units.

1.2 Habitats

Aside from substrate composition, the distribution of benthic habitats and associated communities depends mainly on depth, salinity and temperature, which show pronounced gradients in the Baltic Sea. In addition, anthropogenic pressures such as loss and disturbance to the seabed and nutrient inputs have a strong impact. Eutrophication, rising temperatures, potentially enhanced salinity stratification and concomitant higher primary production can lead to plankton regime shifts and oxygen depletion in deeper areas, thereby altering benthic biotopes and overall food web dynamics. For effective habitat and biotope conservation, as required by the BSAP and HELCOM Recommendations, profound knowledge about interactions between pressures, habitat structure and ecosystem functions are needed. Follow up of status as well as the efficiency of conservation efforts requires harmonized monitoring, mapping, data hosting and processing as well as standardized assessment methods.

While assessment methods exist for parts of Baltic Sea plankton and soft-bottom macrofauna communities, future assessments should also focus on hard-bottom communities. Furthermore, national assessments of benthic soft-bottom communities in coastal waters need to be made comparable at regional level.

Commented [X5]: The Science Agenda TG has agreed to aim at addressing also pelagic habitats under this topic. Such section could e.g. focus on science needs related to hydrographic changes. To be developed at a later stage

Commented [X6]: If included to be rephrased as science needs and placed as part of highlight.

Highlighted science needs

Habitat mapping:

Commented [X7]: To be rephrased in to science needs

- 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;
- Detailed mapping of substrates, communities and pressures for further elaboration of sensitive areas and conflict areas and to steer Maritime Spatial Planning.

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 age and/or size distribution of long-lived species to indicate where pressures adversely affect benthic communities.

Ecosystem functions:

- Assessment of links between benthic habitats/biotopes and ecosystem functions to better understand the role of ecosystem components for ecosystem functioning;
- Development of criteria for estimating the contribution of benthic habitats to ecosystem services to provide evidence that healthy ecosystems benefit human well-being;
- Analysis of traits of benthic habitats/biotopes and food webs in a changing climate and under oxygen depletion.

Habitat restoration:

- Identify areas and methods for the restoration of benthic habitats/biotopes, e.g. habitat-forming species such as seagrass beds, to support nature based-solutions for tackling climate change.

1.3 Food webs

Appropriately functioning 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 by human activities or changing climatic conditions. Signs of deterioration in the Baltic Sea food webs have been found despite the taken management and governance measures (HELCOM Ministerial Declaration, 2018). Both upper and lower levels of food webs are relevant to assess changes in predator-prey interactions as well as the larger scale variations of ecosystem functioning.

For better management of the Baltic Sea protection and conservation, the necessity of understanding the processes between elements of the food webs are stated in several HELCOM reporting 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 is needed;
- 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 and applying existing food web models including all its compartments for detection of horizontal (plankton-benthos) and vertical (lower levels- upper levels) interactions, and further use in protection/conservation measures.

1.4 Marine Protected Areas

HELCOM 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. With regard to biodiversity there is still a lack in implementation of effective conservation measures, partly due to the inadequate understanding of complex ecosystem interactions. An ecologically coherent network of well-managed Baltic Sea Protected Areas (HELCOM MPAs) is an important approach for fulfilling HELCOM ambitions to protect the Baltic Sea. Such a network would ensure that entire ecosystem complexes become more resilient to external threats like eutrophication and climate change. Large no-use areas are important aspects of such a network. However, the current HELCOM MPA network is neither complete nor coherent or well-managed. There is still a need to develop common methods for assessments of management effectiveness and ecological coherence. In addition research on linkages between biodiversity, ecosystem functions and ecosystem services as well as how pressures influence these relationships is necessary. Such investigations should also consider food web aspects, genetic diversity, key species and effects of climate change.

Commented [X8]: This could be relevant for the whole chapter; to consider moving this to the planned introductory text of the chapter as a whole.

[Add reference to key HELCOM agreements]

Highlighted science needs:

Commented [X9]: To be rewritten from questions to stated science needs as under other topics.

Evaluation of spatial protection measures:

- What scientific criteria should be used to identify areas, based on a scientific qualification as no-take zones?
- How can the effectiveness of spatial conservation measures be quantified?
- What scientific tools are adequate for a regular assessment of the effectiveness of spatial protection measures?
- What criteria are appropriate to assess management effectiveness in single MPAs and the network as a whole, respectively?

Ecological coherence

- Which science-based criteria and targets should be used for the HELCOM coherence assessment methodology?
- What parameters justify designation/expansion of MPAs in order to achieve coherence of the MPA network also in relation to climate change?
- Map/model benthic habitats/biotopes and species distribution maps for different climate change scenarios

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HUMAN DIMENSION

[Brief introductory text for the chapter]

Commented [X11]: To be added at a later stage

2.1 Climate change

Commented [X12]: Link to HELCOM agreements/work on climate change to be clarified.

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Climate change in the Baltic Sea region 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 shortening of the sea ice season, diminished ice extent and thickness. Probable, but less certain is decreasing surface salinity. Furthermore, global sea level rise will affect the Baltic Sea coasts, even if the land uplift opposes it in the northern Baltic Sea. Scenario simulations indicate still that significant uncertainties exist on the response of salinity, and particularly on stratification, and circulation to climate change. Significant acidification (decrease in pH) has not occurred in the Baltic Sea yet, probably due to influence from the catchment, but the increasing CO_2 concentration in the atmosphere will result in acidification eventually.

The changes in the physical conditions of the Baltic Sea in response to climate change will most likely result in significant alterations of the ecosystem all the way of the food chain from increased primary production due to faster surface water regeneration to seal population changes due to diminishing sea ice. Decreasing salinity will have drastic effects on species distribution in the brackish part of the Baltic Sea.

Socioeconomic development is occurring concurrent and, in cases, in response to climate change. Recently, frameworks have been developed to understand the interplay between global socioeconomic developments and activities related to pressures in the Baltic Sea region. The 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.

Highlighted science needs:

- Further development of high-quality regionalized scenarios of climate change on the physical environment (hydrography, sea level, sea ice, surface waves) of the Baltic Sea as a basis for both scientific and managerial assessments of the consequences of climate change;
- Further development of scenarios that relates 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;
- 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;
- Effects of temperature increase, oxygen decline, sea level rise and changes in pH on biota, biodiversity and ecosystem functioning should be assessed in relation to climate change;
- Risk assessment of invasive species in relation to climate change induced changes in habitats

2.2 Eutrophication

The water quality of almost the entire Baltic Sea is severely impaired by eutrophication due to the cumulative effect of a century of high anthropogenic nutrient inputs. Despite long-term and partly successful efforts of curbing nutrient inputs, the status has not improved substantially yet and continued reductions of nutrient inputs are needed. This raise the demand of development and implementation of additional measures to reduce the nutrient inputs from waste water, agriculture and other sources. However, there is still a lack of knowledge to optimally plan the measures needed to achieve reductions, and in several cases even knowledge of the efficiency of measures are lacking.

Management of Baltic Sea eutrophication is complicated by the slow response of the system in that it takes decades to demonstrate effects on water quality from implementation of measures. This makes the use of modeling necessary for optimal management.

To reduce eutrophication research is needed in the direction of decrease of loads of nutrients and to decrease the concentrations in the sea.

[Reference to HELCOM nutrient reduction scheme to be added]

Highlighted science needs

Input of nutrients

- Improved and harmonized modelling of the catchment and nutrient sources from the catchment is imperative to improve cooperation to find the most cost-effective way reduce the total nutrient inputs to the Baltic Sea basins by cross-country cooperation.

Measures

- 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;
- Develop efficient nutrient recycling methodologies to transform organic forms of nutrients back to useful inorganic forms.

Nutrient cycling processes

- Investigate the obstacles, both natural and societal, preventing the decrease of nutrient concentrations in the sea including improving understanding and modeling 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, development of harmonized indicators, and understanding and modeling of interactions between the coast and the offshore;
- 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?

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2.3 Hazardous Substances

The Baltic Sea, with its slow water exchange with the North Sea, large population in the catchment and proximity to intensive agriculture and industrialized regions, is heavily loaded with a broad range of chemical pollutants. These substances originate from various anthropogenic sources, especially from industries, consumer products, urban areas, 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 status assessment with respect to hazardous chemicals currently shows that the status is deteriorated, and will continue to be so for a long time due to the high persistence of several indicator substances. The majority of the chemicals used as indicators are legacy pollutants which are strictly regulated at regional and global level, and have been substituted by other less well-known compounds. Additional 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 modeling 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 specific substance groups of concern;
- 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;
- 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.

Status and effects of contaminants:

- Development and harmonization of monitoring methods based on biological effects that capture impact of the total chemical mixture in the marine environment and can function as an early warning leading to further assessment of substances 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.

2.4 Marine litter

Pollution of the marine environment by litter and in particular plastics is a global problem, that was recognized only in the 19X0s and research in the Baltic started in early 2000s. Due to its extensive drainage area and large population, the Baltic Sea is subject to substantial input of litter. Studies on the amount, type and distribution of macro- and microlitter are ongoing, and common guidelines for beach litter surveys have been compiled. However, due to varying methodologies in sampling and sample analyses applied in different research institutes, the collected data is not fully comparable yet. HELCOM has adopted Regional Action Plan on marine litter which includes the commitment to significantly reduce marine litter by 2025 compared with 2015. To reach this goal fundamental knowledge is still needed on the sources of litter as well as on how to sample and assess the presence and impact of litter.

Highlighted science needs

Indicators and impacts of litter:

- Need for harmonized methodology (EU and RUS) for monitoring of beach litter, and microplastics in water and in bottom sediments.

Input and fate of litter:

- Sources and pathways of macrolitter and microplastics;
- Degradation of different type of plastics, including degradation from macro- to microplastics;
- Measures to reduce input of litter;
- Evaluation of effectiveness of management actions e.g. bans of plastics, wastewater treatment to remove microplastics, awareness programmes etc.

Commented [X15]: To be extended.

2.5 Underwater noise

[Draft under development]

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 to the ecosystem. The shallow enclosed nature of the Baltic sea, low salinity and the intense marine traffic makes the Baltic Sea prone to the entrance and settlement of NIS.

Marine NIS most often enter the Baltic Sea with the ballast water of ships or as biofouling on the hulls. Freshwater NIS mainly enter the Baltic through rivers and canals. The Baltic Sea countries cooperate within HELCOM for a harmonized implementation of the International Convention for the Control and Management of Ship's Ballast Water and Sediments (BWM Convention). The Convention requires all ships to implement a ballast water management plan to prevent introduction of new NIS.

Highlighted science needs

Monitoring and mapping of NIS:

- 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;
- Development of reliable species identification methods, including molecular methods;

Status and effects:

- Identify changes in communities, biological processes and habitats caused by NIS;
- Development of a NIS impact indicator (MSFD D2C2) and associated threshold values;
- 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;
- Research on the use of eDNA methods for NIS monitoring and risk assessments.

2.7 Shipping

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

Impacts of shipping are caused e.g. by different air emissions, sewage, introductions of non-indigenous species (NIS) via ships' ballast water or as biofouling, underwater noise and accidental or illegal discharges of oily mixtures. A comprehensive overview of shipping-related impact sources is shown in figure 1. 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 and thus, provided with a higher level of protection than other sea areas.

Whereas some of the pressures have already been addressed, others require the development and implementation of new measures. In the field of shipping, HELCOM primarily works to ensure efficient and harmonized regional implementation of IMO regulations (e.g. MARPOL and BWMC) and at the same time, develops regional initiatives supporting the work at the international level. Further research activities are essential to advance and improve environmental standards, monitoring and assessment, as well as to evaluate the effectiveness / efficacy of potential mitigation measures and to develop innovative sustainable technologies for ships.

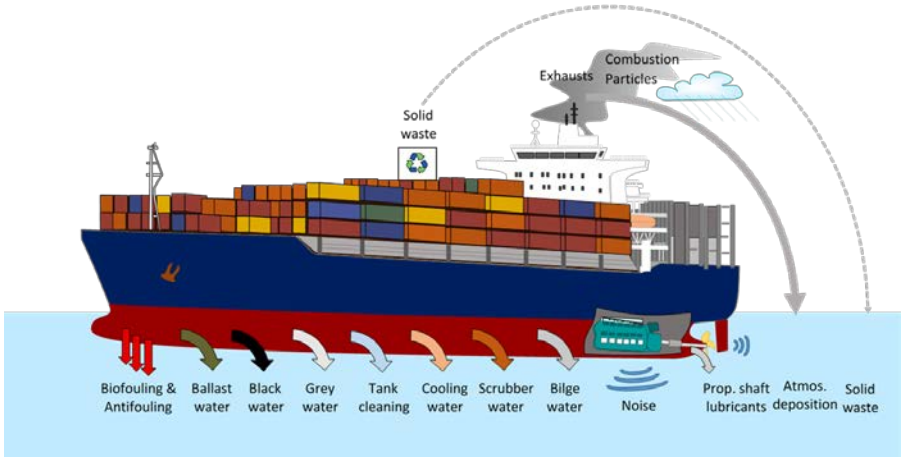

Figure 1: Impact sources of shipping on the marine environment. Illustration by Ida-Maja Hasselöv (BONUS Project SHEBA, 2018).

Highlighted science needs

Monitoring and assessment of pressures from shipping:

- Quantification of hazardous substances like PAHs and heavy metals from scrubber discharge;
- Tools for real-time information and smart monitoring of underwater noise emission;
- High resolution data on shipping activities for cumulative impact assessment.

Development of measures to reduce pressures from shipping:

- Evaluation of effects and consequences of sewage discharges from cargo vessels;
- Research on impact and management of food waste from ships in the Baltic Sea;
- Technical- and management options and impacts of grey water discharges from cargo vessels;
- Evaluation of effects of scrubber wash water from open loop and hybrid systems;
- 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.

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;
- 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 generate critical amounts of bycatch of endangered species, and bottom trawling cause disturbance to sensible benthic habitats. A great proportion of the fleet in the Baltic Sea consists of small-scale fisheries. Due to missing reporting requirements, there is too few data available in order to quantitatively assess resulting impacts An advanced reporting as well as research on fisheries impacts and mitigation measures is needed to improve fisheries management that enables reaching a good status of habitats and species and achieving ecologically sustainable fisheries.

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 of commercial fish stocks in order to establish sustainable use of local stocks;
- 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:

- Evaluation of employed bycatch mitigation measures such as acoustic deterrence devices 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.

Commented [X16]: Consider whether to move all issues related to spatial measures to 'MPA'?

2.9 Cumulative impacts

[Lead country is missing]

3 HOLISTIC APPROACHES

[Add brief introductory text for the chapter]

Commented [X17]: To be added at a later stage.

3.1 Economic and social analyses

Economic and social analyses are needed to fully apply ecosystem-based management in the Baltic Sea and to support the sustainable use of marine resources. Economic and social analyses contribute to ecosystem-based marine management, marine spatial planning, pollution mitigation, and integration and implementation of policies. The concept of ecosystem services includes measurable benefits the people can obtain from ecosystems (Müller et al., 2015) and therefore is used as a tool in the economic and social analyses Identification of ecosystem services provides option to quantify the impacts on ecosystems, find the gaps and contribute to information pool necessary for sustainable use of these services. As a part of World Ocean, the Baltic Sea also supplies numerous ecosystem services as benefits for human economic activity and existence well-being.

Although process of employing economic and social analysis in HELCOM assessments has already started additional knowledge is still needed for valuation and analysis in order to apply ecosystem approach successfully (HELCOM Ministerial Declaration, 2018). Highly relevant for the Baltic Sea is also use of ecosystem services for assessment of the efficiency of protection and management measures.

The translation of natural values into the monetary information calls for new approaches and methods. Compiled research needs include steps for implementing the decisions of HELCOM planning documents.

Highlighted science needs

- Better understanding how the overall status of marine environment is related to changes in economic activity, also in a spatial aspect;
- Development and testing of approaches and tools for marine accounting;
- Evaluation of costs and benefits of changes due to different management scenarios foreseen in policy planning documents (e.g. BSAP);
- Research on linkage of marine state components to ecosystem services, related benefits and values;
- Development of approaches and assessments integrated with marine ecosystem services;
- Development of criteria to quantitatively describe ecosystem services.

3.2 Ecosystem approach

The concept for an ecosystem approach was originally developed under the UN Convention on Biological Diversity. HELCOM and OSPAR subsequently 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.

In 2010, the ecosystem approach was incorporated into 10 common HELCOM and VASAB maritime spatial planning principles, where it is considered as an overarching principle. In 2016 followed a HELCOM and VASAB Guideline for the implementation of an ecosystem-based approach in Maritime Spatial Planning in the Baltic Sea area.

Highlighted science needs

Commented [X18]: To be rewritten from questions to stated science needs as under other topics.

Implementation of the Ecosystem approach

- How far has the ecosystem approach in the Baltic Sea Region has been implemented?
- Under what circumstances should the precautionary principle been applied?
- How can the provisions of the Paris Agreement be incorporated into the ecosystem approach concept for the Baltic Sea?
- What are the approaches, measures and instruments to improve the state of ecosystems in the Baltic Sea (through e.g. renaturation)?

Ecosystem approach in MSP

- What are transparent spatial planning tools for a comprehensive consideration of ecosystem components?
- Which role plays the ecosystem approach in sectoral planning (e.g. offshore wind energy) in relation to the (holistic) marine spatial planning?
- How to establish a comprehensive marine, ecosystem-oriented landscape planning in the Baltic Sea area?

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.

External initiatives

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.

HELCOM will also provide the Science Agenda as a contribution to the UN Decade of Ocean Science which will run from 2021-2030. The aim of the UN initiative is to create a common ocean science framework that can support countries in achieving the UN Sustainable Development Goals and turn 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. 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.

Commented [X19]: This text needs to updated based on status of BANOS by end of 2020.

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, Examples

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 mapping 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

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S=State
S/I= Impacts on state components
I=Social impacts
R=Response (Measures)

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/

Field Code Changed

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	BSAP Roadmap on fisheries data	A, P	A healthy and resilient ocean A sustainably harvested ocean	14.4, 14.2
Applied research on alternative methods for assessing and managing of commercial fish stocks in order to establish sustainable use of local stocks	Assessment	BSAP	P, S/I	A healthy and resilient ocean A sustainably harvested ocean	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	BSAP	S/I	A healthy and resilient ocean A sustainably harvested ocean	14.2
Evaluation of employed bycatch mitigation measures such as acoustic deterrence devices in order to advance bycatch mitigation measures;	Mapping Measures, evaluation	BSAP Roadmap on fisheries data	P, R	A healthy and resilient ocean A sustainably harvested ocean	14.4, 14.2
Development and testing of new technical measures or modification of existing gear directed to fishing methods to decrease bycatch of seabirds, marine mammals and protected fish species;	Measures, development	BSAP	R	A healthy and resilient ocean A sustainably harvested ocean	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	BSAP HELCOM Rec 35/1	R	A healthy and resilient ocean	14.2
Calculation/modelling of socio-economic aspects of fisheries affecting benthic habitats and fisheries management options throughout different métiers, performance of cost-benefit analyses;	Socio-economic impacts	BSAP	I	A sustainably harvested ocean	14.2
Evaluation of management measures (e.g. spatial-temporal closures of fisheries, No-take areas) to avoid/ reduce bycatch of threatened and declining species	Measures, evaluation	BSAP HELCOM Rec 35/1	R	A healthy and resilient ocean	14.2

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 based and sea based, and modeling of relative importance of different transport routes to support development of efficient measures targeting chemical contamination of the Baltic Sea in general and specific substance groups including pharmaceuticals and PFASs.	Input of pressure, Modeling	BSAP	P	A clean ocean where sources of pollution are identified and removed	14.1, 12.4
Retrospective time trend analysis to assess efficiency of implemented measures and interactions with multiple pressures and stressors - both old and newer contaminants such as organohalogens, incl. brominated and perfluorinated compounds, mercury, even microplastics.	Level of pressure Measures, evaluation	BSAP	P, R	A clean ocean where sources of pollution are identified and removed	14.1
Implement source- and environmental screening campaigns of contaminants of emerging concern (CEC) originating from land and sea based sources 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.	Input of pressure, Modeling, Risk assessment	BSAP	P	A clean ocean where sources of pollution are identified and removed	14.1, 12.4
Development and harmonization of monitoring methods based on biological effects.	Impacts	BSAP	S/I	A healthy and resilient ocean, A clean ocean where sources of pollution are identified and removed	
Research on the fate of risk-bearing substances, in the environment, based on calculation and screening, should be promoted to better understand their emissions and the need for risk reduction measures (e.g. advanced wastewater and stormwater treatment)	Pressures, Impacts	BSAP	P, S/I	A clean ocean where sources of pollution are identified and removed	14.1, 12.4