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Background

The Pan Baltic Scope (2018-2019) project's activity 1.2.4 is devoted to Green Infrastructure and involves the following tasks:

- To outline the concept of 'green infrastructure' (GI) by utilizing previous and ongoing studies and projects;
- To test the concept by utilizing the available data (e.g. developing Baltic-wide maps on benthic habitats, including those that are important for fish species (Essential Fish Habitats maps));
- To collect feedback on the draft concept from the HELCOM State and Conservation Working Group (took place in May 2019) and HELCOM-VASAB MSP Working Group.

At the moment report on marine green infrastructure concept is prepared and will be available in the end of 2019. Attached document is a summary (brochure) of this report with an overview of the concept of GI, its existing definitions and policy context, as well as existing approaches to GI mapping. Further document contains description of Pan Baltic Scope approach to marine GI mapping with the description of suggested components of marine GI, the assessment criteria and available data sets for GI mapping at the Baltic Sea scale. Finally conclusions are presented with regard to the possibilities and future research needs for marine GI mapping within the Baltic Sea region, and the applicability of this information in the MSP process.

The Pan Baltic Scope project defines marine green infrastructure as a spatial network of ecologically valuable areas which are significant for the maintenance of ecosystems' health and resilience, biodiversity conservation and multiple delivery of ecosystem services essential for human well-being.

The proposed concept of marine GI can support planners in applying ecosystem-based approach in MSP as well as nature conservation authorities in assessing coherence of the MPA network. However, the methodology, proposed by the Pan Baltic Scope project, needs to be developed further to include a connectivity analysis of ecologically valuable areas, a more comprehensive ecosystem service assessment and an improvement in input data quality.

The following comments have so far been noted on the brochure:

- In the maps on ecological value and ecosystem services, the word to describe legend values (currently "value") should preferably be omitted or replaced by some more neutral word in line with the intention of the maps.
- The captions and headings associated with figures 5-9 should preferably be clarified as "aggregated map of areas important for ecological value".

Action required

The Meeting is invited to <u>discuss</u> Pan Baltic Scope approach for mapping of marine Green Infrastructure and its future applicability in MSP.

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Mapping of Marine Green Infrastructure:

Pan Baltic Scope Approach

September 2019

Mapping of Marine Green Infrastructure: Pan Baltic Scope Approach

Authors: Anda Ruskule[1], Lena Bergström[2], Jan Schmidtbauer Crona[3], Jonne Kotta[4], Philipp Arndt[5], Solvita Strāķe[1], Sandra Sprukta[1], Didzis Ustups[1], Ingūna Urtāne[1]

[1] Ministry of Environmental Protection and Regional Development of the Republic of Latvia
[2] HELCOM
[3] The Swedish Agency for Marine and Water Management
[4] Ministry of Finance of Estonia/Estonian Marine Institute, University of Tartu
[5] Federal Maritime and Hydrographic Agency (BSH), Germany

Photos:

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Content

1 Introduction

Green Infrastructure (GI) is an emerging concept which helps to integrate ecological aspects into spatial planning and decision making on land and sea use management. Already since the 1980s scientists have been suggesting that ecosystems can be considered as a type of infrastructure which generates benefits and welfare to society. Over the past decade the concept of GI has been introduced in many EU policy documents and initiatives. Developing GI is acknowledged as a key step towards successfully implementing the EU Biodiversity Strategy 2020. Also, the EU policy on maritime affairs and fisheries refers to GI as a tool contributing to sustainable development of coastal areas.

By now the concept is relatively well established with regard to terrestrial areas, while its application in maritime environment is a novelty. Also, the review on the progress of the implementation of the EU GI strategy, published by the European Commission in May 2019, recognises that GI is not sufficiently addressed in maritime spatial planning, despite the fact that it could contribute to healthy marine ecosystems and delivery of substantial benefits, including food production, recreation and tourism, climate change mitigation and adaptation, etc.

The Pan Baltic Scope project has taken a challenge to develop a concept for marine GI applicable in maritime spatial planning and to test GI mapping at the Baltic Sea scale. The Pan Baltic Scope expert group has mapped the areas of high ecological value and associated supply of ecosystem services and has aggregated this information into a synthetic map of marine GI of the Baltic Sea.

The results of this GI mapping exercise shall be taken as a first attempt towards developing a comprehensive methodology for mapping marine GI. Further work is required to improve the knowledge base on how marine ecosystem functions and its role in maintaining biodiversity and human well-being. In this publication we outline the concept of marine GI, describe the mapping approach applied by the Pan Baltic Scope project and the obtained results, as well as discuss opportunities to apply the concept in ecosystem-based maritime spatial planning. To learn more about different ways of mapping marine GI and the methods applied by the Pan Baltic Scope project, please, read the report on “Green Infrastructure Concept for MSP and Its Application Within Pan Baltic Scope Project”, available on the project website: http://www.panbalticscope.eu

2 Background: What is marine green infrastructure?

EU policy context

The concept of green infrastructure (GI) was first introduced in the EU environmental policy within the EU Biodiversity Strategy 2020. Target 2 of the strategy requires that "by 2020, ecosystems and their services are maintained and enhanced <u>by establishing green infrastructure</u> and restoring at least 15 % of degraded ecosystems." Following the tasks set in the Biodiversity Strategy, the European Commission adopted an EU strategy on green infrastructure (GI strategy) [1] in 2013.

The GI Strategy defines green infrastructure as *"strategically planned network of natural and semi-natural areas with other environmental features designed and managed to deliver a wide range of ecosystem services. It incorporates green spaces (or blue if aquatic ecosystems are concerned) and other physical features in terrestrial (including coastal) and marine areas*." Thus, the multifunctionality of ecosystems in providing benefits for both humans and nature is featured as the essence of the GI concept.

The definition highlights three main components of GI:

- **network of natural and semi-natural areas**: maintaining biodiversity and areas of high ecological value is at the core of GI, given that it is expected to support achieving the aims of EU Biodiversity Strategy. The network of Natura 2000 areas serves as a backbone (or core areas) of the EU-wide GI network. The connectivity of the network is an essential functional characteristic of GI.
- **delivery of a wide range of ecosystem services**: the GI concept is services oriented. A well-managed network of green and blue space can improve environmental conditions and therefore citizens' health and quality of life. The ecosystem services provided by GI includes water purification, mitigation and adoption to climate change, maintenance of habitats for species as well as space for recreation, etc.
- **strategic planning**: strategic and integrated planning process is required to ensure that GI core areas are spatially and functionally connected as well as to improve human well-being through multifunctional use of ecosystems. Spatial planning is

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[1] EC, 2013. Green infrastructure (GI) – Enhancing Europe's Natural Capital. COM(2013)249.

recognised as the most effective way for deploying GI, by guiding potentially harmful developments away from sensitive nature areas as well as by identifying best locations for habitat enhancement/restoration projects to reconnect healthy ecosystems. The strategic approach allows local scale GI initiatives or projects to be scaled up or cumulated to a higher level, contributing to the coherence and functionality of the network. At the same time national, regional or pan-European scale GI mapping can indicate where an action shall be taken at local level.

Approaches to GI mapping

Following the objectives and tasks set by the EU Biodiversity Strategy 2020 and GI Strategy, several initiatives on GI mapping and strategic planning have been launched, ranging from local scale projects up to EU level studies. The best practice cases of GI mapping at European, national, regional and local levels were analysed by the Joint Research Centre (JRC), the EEA and the Directorate-General for Environment of the European Commission in a joint report, published in 2019[2]. The report provides guidance for the strategic design of a well-connected, multifunctional and cross-border GI, describing how geospatial methods, data and tools can be used at various geographical scales. The report also indicates a significant gap in knowledge regarding the deployment of marine GI. It states that *"the provision of a conceptual framework, data and tools for the mapping and assessment of marine ecosystems and their services (a marine MAES) would certainly help deploy a marine GI, particularly at the sea-land interface."*

The JRC report presents a conceptual framework for planning strategic GI, highlighting two complementary approaches to GI mapping:

- **physical mapping of existing GI components**, including protected areas, ecological networks and other valuable natural areas;
- **ecosystem service-based mapping**, including provisioning, regulating and cultural services.

The two approaches are presented as interconnected and complimentary perspectives, since GI is formed by biodiversity rich habitats, which provide multiple ecosystem services.

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[2] Estreguil et al., 2019. Strategic Green Infrastructure and Ecosystem Restoration: geospatial methods, data and tools, EUR 29449 EN, Publications Office of the European Union, Luxembourg, JRC113815

Application of GI concept to marine areas

As highlighted in the definition provided by the European Commission, GI shall incorporate green (and blue) spaces and other physical features in terrestrial as well as marine areas. However, approaches to mapping green or blue space forming GI may vary significantly depending on scale and ecosystem type. GI components can be relatively easily identified in terrestrial areas – these are patches of natural or semi-natural habitats within urban or rural areas, forming the core zones of ecological networks, as well as ecological corridors connecting them. Yet, the situation is more complicated in marine environment, which is formed by one interconnected, dynamic and comparatively natural ecosystem. Therefore, a more elaborated approach is required to address the complexity of the marine ecosystem. Moreover, unlike with terrestrial areas, where remarkable experience and knowledge base on GI mapping has been generated, mapping of marine GI is still a novelty.

Marine GI should include multifunctional areas of high ecological value, essential for maintaining biodiversity and functioning of marine ecosystem as well as ecosystem service supply. A typical example of marine GI is shallow vegetated habitats, e.g. reefs (Figure 1), which provide habitats for various species, nursery and spawning ground for fish, improves of water quality by filtration of nutrients provided by mussels, prevents of coastal erosion etc.

In order to assess potential ways of mapping marine GI, the Pan Baltic Scope project has analysed the existing experience in mapping ecological values within the Baltic Sea region. In a survey carried out by the project 19 existing national-scale attempts at mapping ecologically valuable or sensitive areas as well as ecosystem service supply were identified. These cases represent a considerable variety of approaches towards determining the value of the area. In nine of the cases, different methods for aggregation of the data on biotic features (e.g. distribution of benthic habitats, bird, fish and mammal species) and geological features were applied to estimate the ecological value of the area.

Furthermore, during the first Pan Baltic Scope GI workshop, held in Riga, 29-30 May 2018, the participants identified various components or aspects which are essential for mapping marine GI. These include different features and data sets that characterise ecological value of marine areas:

- an already designated network of the existing marine protected areas (MPAs);

- the ecologically or biologically significant marine areas (EBSAs) proposed within the framework of the UN Convention on Biological Diversity and defined as larger special areas that serve important purposes "to support the healthy functioning of oceans and the many services that it provides";
- latest spatial information on distribution of benthic habitats of high conservation value; areas important for the main species groups (birds, fish, mammals) at different life stages; ecosystem components vulnerable to human pressures; as well as areas important for connectivity of the core habitats;
- information on marine ecosystem functions and service supply, including supporting services as well as provisioning, regulating and cultural services.

Thereby, the definition and delineation of marine GI can encompass various criteria which characterise the marine ecosystem, its biological values, functionality and service supply. A coherent mapping of marine GI would require spatially referenced and harmonised data sets as well as a balanced representation and sensible aggregation of data on different marine features. Furthermore, marine GI mapping should also include a connectivity analysis of core habitats and consideration of land-sea interactions.

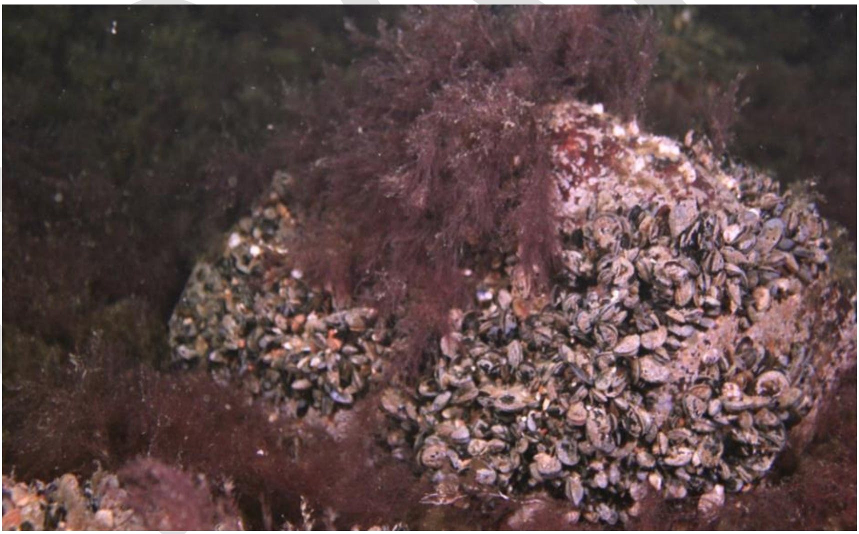


Fig. 1 Reefs form an essential component of marine GI
(Photo by the Latvian Institute of Aquatic Ecology)

3 PBS approach to mapping GI

The Pan Baltic Scope project aimed to develop tools and approaches to contribute to coherent maritime spatial plans in the Baltic Sea Region, including implementation of an ecosystem-based approach and GI planning. This included testing the application of GI concept and the approach to mapping marine GI at the Baltic Sea scale by utilizing the available data.

The Pan Baltic Scope approach to GI mapping included the following steps:

1. **Identification of the components forming marine GI** and selection of suitable data sets for GI mapping;
2. **Mapping areas of high ecological value**: the selection of relevant assessment criteria; the assessment of marine ecosystem components against the selected criteria; the development of an aggregated ecological value map;
3. **Mapping ecosystem service supply potential**: the selection of ecosystem services relevant in the context of marine GI; the assessment of marine ecosystem components against the selected ecosystem services; the development of an aggregated ecosystem services map;
4. **Development of the GI map** by integrating the results of mapping ecological value and ecosystem services.

Fig.2. Pan Baltic Scope expert group discuss the marine GI concept at a project meeting in Gothenburg, 10-11 September 2018

The presented approach to marine GI mapping is in line with the definition proposed by the EC Communication on Green Infrastructure. The project team has interpreted the definition in relation to marine context.

The Pan Baltic Scope project defines marine GI as a spatial network of ecologically valuable areas which are significant for the maintenance of ecosystems' health and resilience, biodiversity conservation and multiple delivery of ecosystem services essential for human well-being.

One options to identify ecologically valuable areas could be based on the existing network of MPAs or the areas proposed as EBSAs. However, the project experts concluded that such an approach would not be sufficient due to data limitations at the time of designating MPAs and EBSAs. Therefore, it was agreed to apply a bottom-up approach by aggregating spatial data on the distribution of benthic habitats, birds, fish and mammals to identify areas of high ecological value as well as ecosystem service supply potential. The areas scoring the highest values are considered to be those that form marine GI (Figure 3).

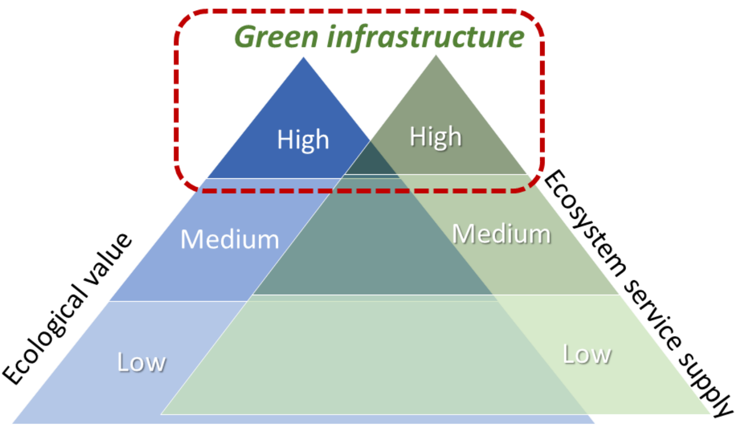


Fig.3. Pan Baltic Scope approach to mapping marine GI

3.1. Available data for GI mapping at the Baltic Sea scale

GI mapping requires consistent and reliable data on the extent and condition of ecosystem components which form GI and the services they provide. The Pan Baltic Scope project was aiming to test marine GI mapping by utilising the available data. Regionally harmonised spatial data sets on the marine ecosystem components covering the whole Baltic Sea were available from the HELCOM Maps and Data services, prepared within the HELCOM HOLAS II project.

The dataset includes more than 30 layers on spatial patterns of various ecosystem components of the following broader groups:

Habitats:

- Pelagic habitats
- Benthic habitats and species:
  - Marine landscapes
  - EU protected (Natura 2000) habitat types
  - Presence of key benthic species
- Essential fish habitats
- Bird habitats

Mobile species:

- Presence and abundance of fish species
- Presence and abundance of mammals

However, not all data layers were suitable for GI mapping. The data on the distribution and abundance of mobile species were not included in the aggregated maps of ecological value, ecosystem service supply and GI due to insufficient data accuracy. The data on pelagic habitats (represented by the data layer on productive surface waters) were not included in the analysis because of lack of any spatial differences. The former HELCOM data layers on essential fish habitats were replaced by new maps developed within the Pan Baltic Scope project, reflecting spawning areas of cod, sprat, herring, European flounder, Baltic flounder, as well as recruitment areas of perch, pikeperch, and nursery areas of flounder.

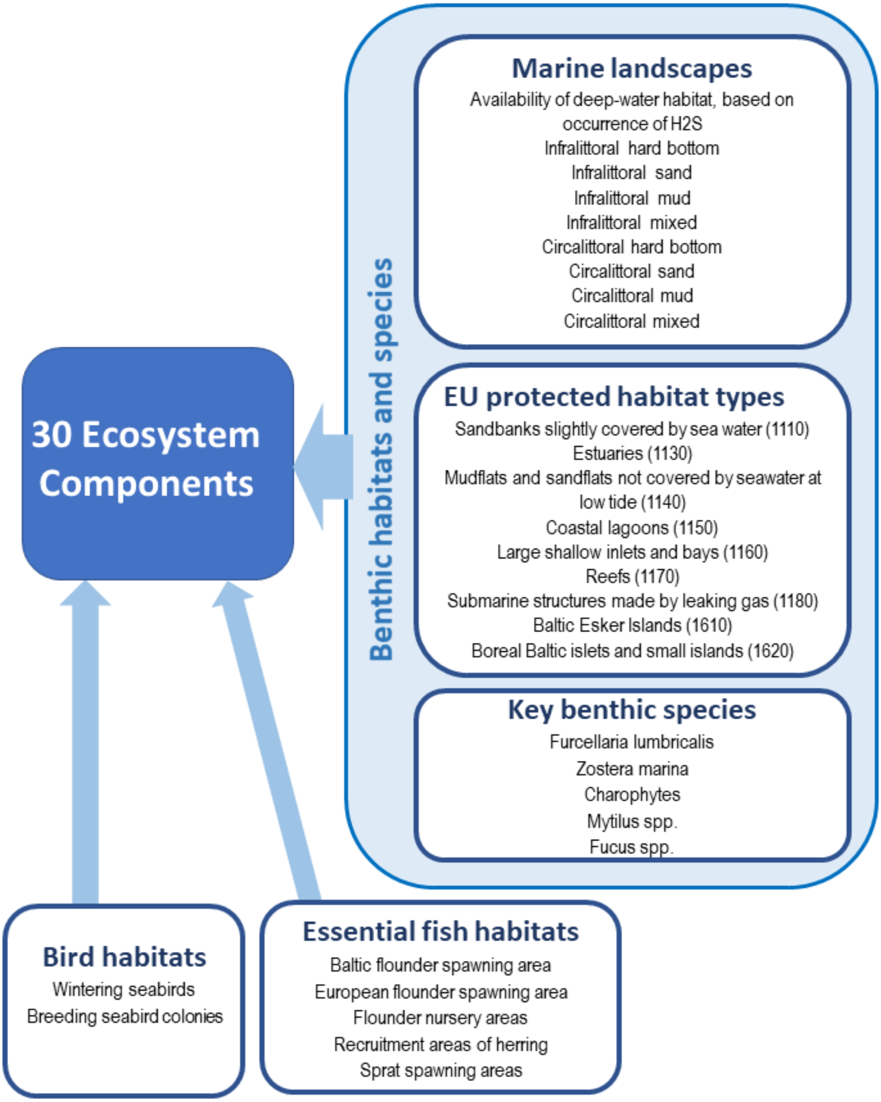


Fig.4. Data layers on ecosystem components used by the Pan Baltic Scope for marine GI mapping

3.2. Mapping marine ecosystem value

The ecological value of marine areas was assessed in relation to their importance for the maintenance of biodiversity. Pan Baltic Scope experts decided to use the criteria applied in the identification of ecologically or biologically significant marine areas (EBSAs), namely: biological diversity; rarity; importance for threatened, endangered or declining species and/or habitats; vulnerability, fragility, sensitivity, or slow recovery; special importance for life-history stages of species; and biological productivity.

To obtain maps representing areas of high ecological value in the Baltic Sea, 30 ecosystem components (presented in Figure 4) as well as marine mammals were assessed with regard to their relevance to the six criteria listed above. A matrix was developed to represent all possible combinations of ecosystem components and criteria. Value 1 was assigned if the ecosystem component was identified as relevant for that criterion, while other combinations were assigned value 0.

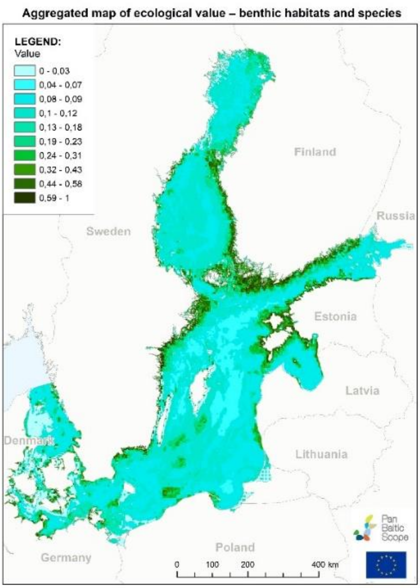


Fig.5 Aggregated ecological value of benthic habitats and species

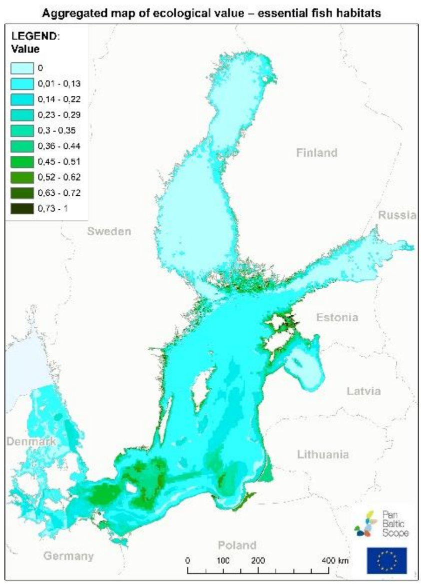


Fig.6 Aggregated ecological value of essential fish habitats

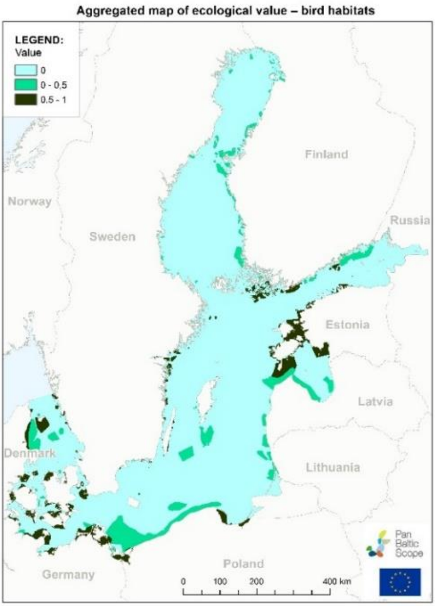


Fig.7 Aggregated ecological value of bird habitats

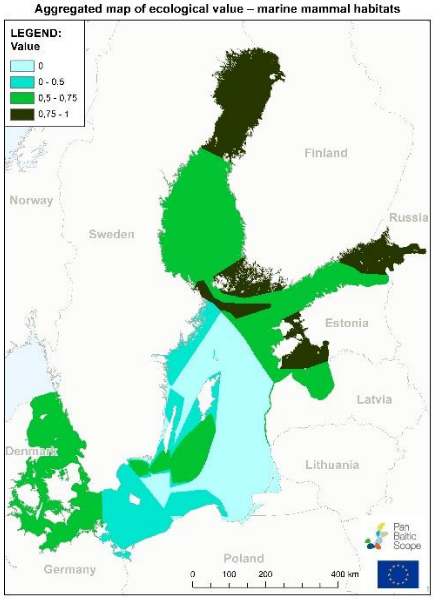


Fig.8 Aggregated ecological value of marine mammal habitats

The synthetic maps of ecological value were developed using hierarchical data aggregation method. Step 1 produced separate maps for each ecological value criterion in relation to each ecosystem component group - benthic habitats, birds, fish and mammals (24 maps). Step 2 produced aggregated maps at the level of ecosystem component groups (4 maps, Figures 5-8). Step 3 produced a composite aggregated ecological value map by merging the aggregated maps from Step 2 (Figure 9).

It is evident from the results obtained that the maps representing areas of ecological value to mammals were not sufficiently accurate - the current data sets on seals (as used in the BSII of HOLAS II) represent the total distribution area of seals in a very coarse way, which gives rise to boundaries with little biological meaning in the resulting maps (Figure 8). Therefore, the project expert group decided to remove the component of mammals from further data aggregation exercise for the time being. Also, the accuracy of the bird data is not sufficient, leading to a slightly exaggerated value of bird habitats within the aggregated ecological value map.

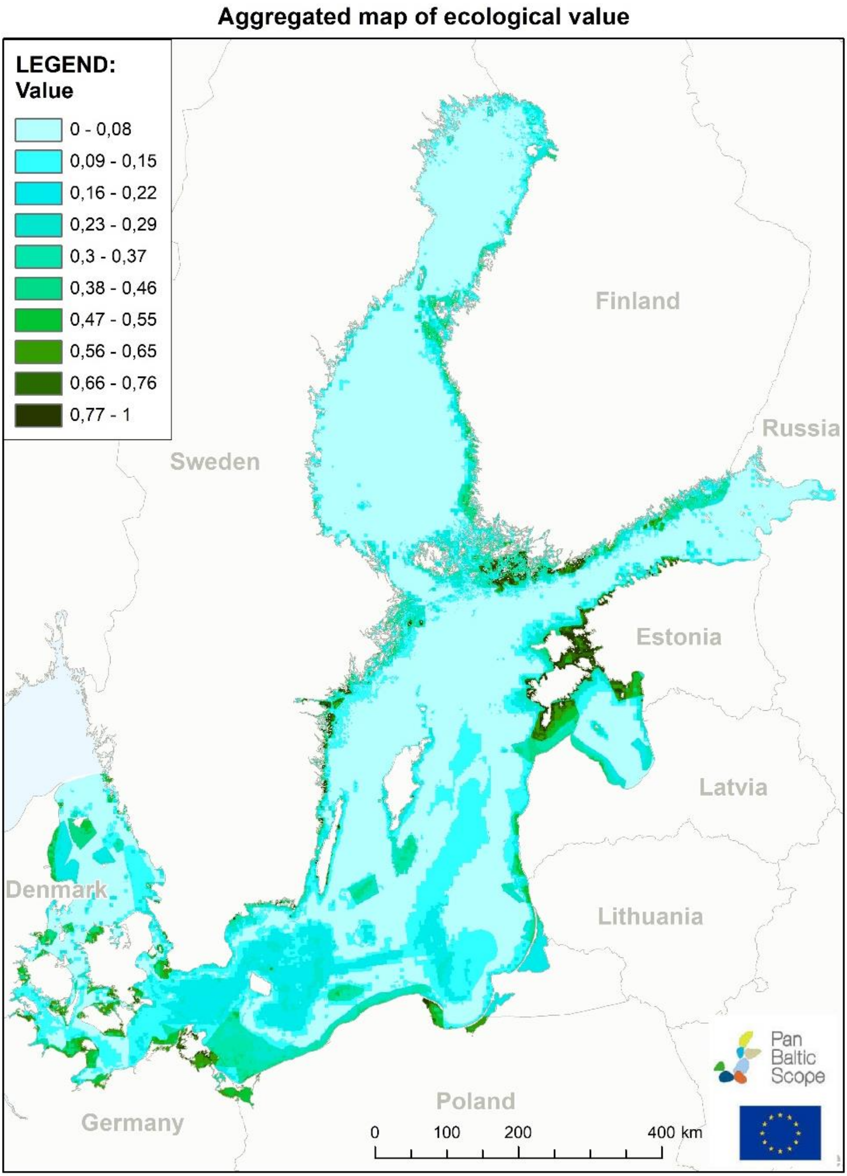


Fig.9 Aggregated map of ecological value

3.3. Mapping marine ecosystem services

As described above, the emphasis within the GI concept is placed on multifunctionality of ecosystems in providing benefits for both humans and nature. Ecosystem services demonstrate how ecosystem structure and function contributes to human well-being. The ecosystem service mapping performed within the Pan Baltic Scope project focused on the potential of ecosystem structure (characterised by various ecosystem components) to deliver various services.

Ecosystem service mapping followed a similar approach as in the case of ecological value mapping. First, the experts identified the ecosystem services which are relevant in the context of marine GI and could be assessed based on the available data sets. It was decided to focus on regulation and maintenance services as well as cultural services (related to recreation) since they are better suited to the concept of GI. The selection was based on the Common International Classification of Ecosystem Services (CICES), Version 5.1 (published in 2018). Two of the CICES ecosystem service classes were further specified, providing sub-categories based on ecosystem service assessment work within the BONUS BASMATI project. All ecosystems services potentially relevant for mapping GI as well as the services selected by the Pan Baltic Scope project are presented in Figure 10.

Each of the 30 ecosystem components (presented in Figure 4) was assessed regarding its potential contribution to each of the selected ecosystem services. For that purpose, a second matrix was developed, where value 0 was assigned in case of no or negligible contribution, while value 1 was assigned when the ecosystem component was considered to contribute to the service.

The matrix results were used as a basis for developing maps on ecosystem service supply potential. However, in order to avoid domination of those ecosystem features that were represented by many data layers (e.g. benthic habitats) and thus double counting of the ecosystem service supply value, a slightly different hierarchical data aggregation approach was applied. Step 1 mapped each ecosystem service provided by each ecosystem component sub-group (marine landscapes, Natura 2000 habitats, key benthic species, essential fish habitats and bird habitats). Step 2 produced aggregated ecological value maps for the ecosystem component groups. Step 3 produced a composite aggregated ecosystem service map.

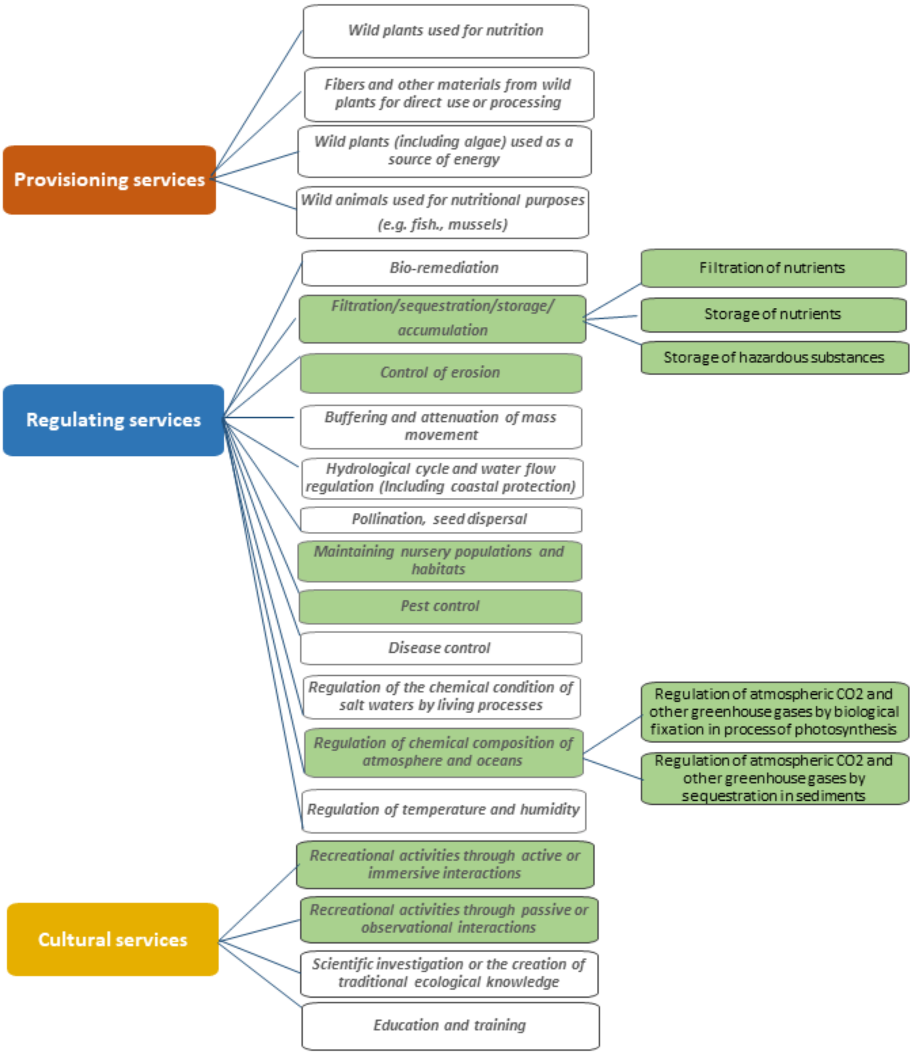
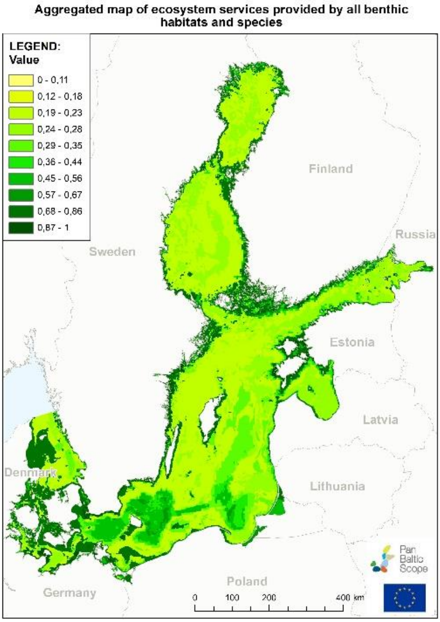


Fig. 10. Ecosystem services (CICES V5.1) potentially relevant for mapping marine GI (services marked in green were assessed by the Pan Baltic Scope project).



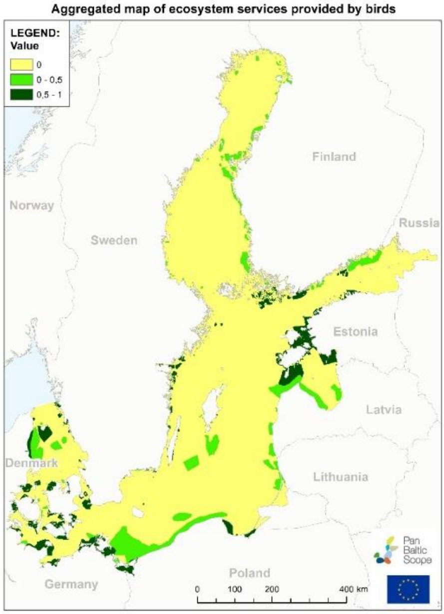


Fig.11 Aggregated map of ecosystem services provided by benthic habitats and species

Fig.12 Aggregated map of ecosystem services provided by birds

Through Step 1 a total of 37 single ecosystem service maps were obtained which illustrate 10 ecosystem services provided by five ecosystem component sub-groups. The single ecosystem service maps were summed up in the five sub-groups and further combined into two ecosystem component groups (benthic habitats and birds) as presented in Figure 11 and 12. The aggregated ecosystem services map, which sums up the values of the aggregated benthic habitat and fish maps, is presented in Figure 13.

The aggregated map indicates the multi-functionality of the areas in relation to ecosystem service supply, where higher value is shown for areas that have a potential to deliver more ecosystem services. However, the same as with ecological value mapping, the value of bird habitats is slightly exaggerated within the aggregated ecosystem service map due to insufficient accuracy of the bird data.

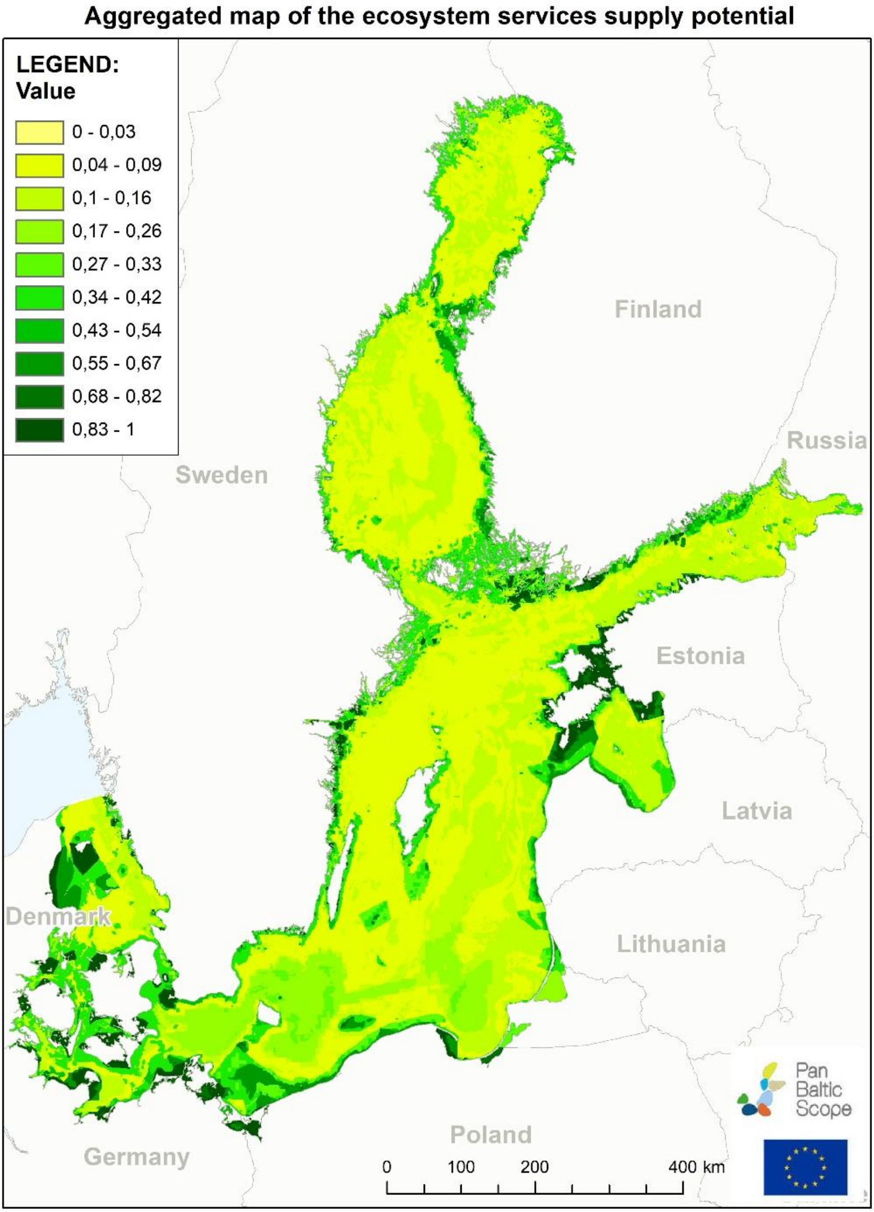


Fig.13 Aggregated map of the ecosystem service supply potential

3.4. Producing an aggregated GI map

The final map of marine GI aggregates the results of mapping areas of high ecological value (Figure 9) and the potential for ecosystem service supply (Figure 13). Marine GI is formed by the areas which have the highest ecological value and/or highest value for ecosystem service supply. This is in line with the EC definition of GI, which should encompass a network of areas managed for protection of biodiversity and delivery of a wide range of ecosystem services.

However, unlike with terrestrial areas, where patches of green or blue space have a distinct border, such borders hardly ever exist in marine environment. Therefore, defining a threshold above which an area would be considered of a high value is rather an arbitrary decision taken by experts or decision makers. Different approaches can be applied to defining areas of the highest value. The Pan Baltic Scope experts have proposed that the 30 % of the Baltic Sea area with the highest scores for aggregated ecological and ecosystem service supply value should be recognised as marine GI (Figure 14).

Although the mapping results give indicative information on GI of the Baltic Sea, the presented approach has certain limitations, which should be addressed in future studies:

- More accurate data sets are required on distribution of marine ecosystem components. This applies in particular to distribution or abundance of mobile species (e.g. birds and mammals). Compilation of such data sets could follow the same approach as applied by the Pan Baltic Scope project for the mapping of essential fish habitats.
- Ecological value mapping should include species-specific connectivity analysis, which is an essential criterion for functionality of ecological networks. This includes an analysis of the conditions for spreading of species and functional interconnection between sites important at different life stages of the species, etc.
- A more comprehensive approach to ecosystem services mapping should be applied which would consider spatial variations in biota and the functioning of marine ecosystem, involve the assessment of ecosystem condition, vulnerability to cumulative pressures, and take into account ecosystem service supply and demand relation.

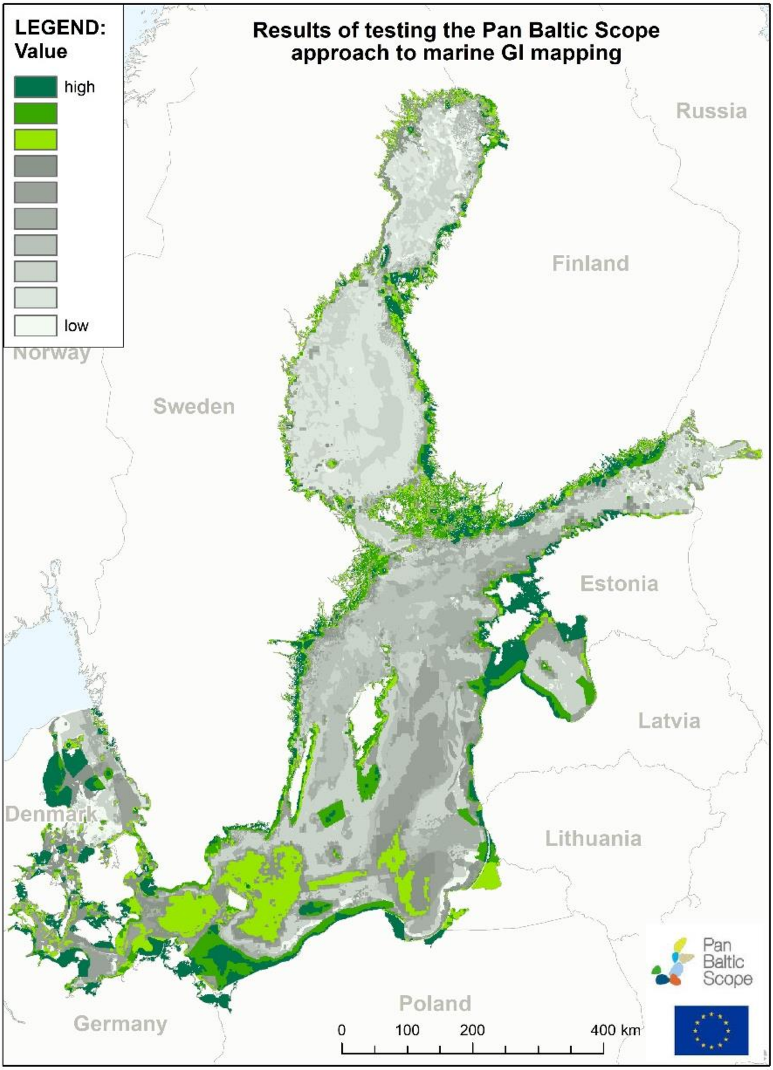


Fig.14 Results of testing Pan Baltic Scope approach to marine GI mapping based on available spatial data: green colour indicates the 30 % of the Baltic Sea area which represents the highest ecological and ecosystem service supply value (the most valuable areas in dark green, other highly valuable areas in light green).

4 Potential for applying GI concept in MSP

In addition to its role in maintenance of biodiversity, GI is recognised as a tool for spatial planning that can enhances human well-being and quality of life through multifunctional use of ecosystems. GI mapping helps to integrate ecological aspects and information on ecosystem service supply into land and sea use planning and decision-making. Thus, GI mapping provides an essential input for the implementation of the ecosystem-based approach (EBA) in MSP. The GI concept contributes to several key elements of EBA, including best knowledge and practice, identification of ecosystem services, relational understanding, precaution, mitigation, subsidiarity and coherence as well as participation and communication.

- GI mapping helps to develop the knowledge base on marine ecosystem structure, functions and service supply and thereby contributes to relational understanding of interrelation between ecological and social and economic systems.
- Consideration of GI mapping results in development of sea use solutions can help to guide away potentially harmful development from ecologically valuable or sensitive areas, thus contributing to precaution principle.
- GI mapping results can be used in SEA of the MSPs assessing single and cumulative impacts on marine ecosystem and service supply and thereby improving the relational understanding on interactions between human activities and ecosystem.
- The Baltic Sea scale GI mapping can be used to support cross-border coordination of planning solutions as well as to identify areas where solutions are needed at local level. This would be a step towards a strategic planning of marine GI at the sea basin level, as well as contribute to the principle of subsidiarity and coherence.
- GI concept can help to facilitate communication across sectors and stakeholder groups and improve the understanding of marine ecosystem functioning, potential and limitations for the use of the sea.

Furthermore, giving consideration to GI mapping results within MSP can help to improve the connectivity of the MPA network or functionally related parts of the ecosystems, e.g. by avoiding sea uses which increase fragmentation of habitats or create obstacles for species migration. GI mapping can also help to identify areas of high ecological value, which potentially can be considered for extending the MPA network.

5 Conclusions

The Pan Baltic Scope project interprets marine GI as a spatial network of ecologically valuable marine areas significant for the maintenance of ecosystems' health and resilience, biodiversity conservation and multiple delivery of ecosystem services essential for human well-being.

Deployment of GI in terrestrial as well as marine areas is recognised as a key tool for halting the loss of biodiversity and implementing the objectives of EU Biodiversity Strategy 2020. At the same time, as noted in the EC Guidance on deployment of EU-level green and blue infrastructure, "healthy, resilient and productive ecosystems are a necessary pre-requisite for a smart, sustainable and inclusive economy." Therefore, maintenance of marine GI is also essential for reaching objectives of the EU Blue Growth strategy.

Unlike in the case of terrestrial ecosystems, mapping marine GI is still a novelty. A significant gap in knowledge regarding the deployment of GI in the marine environment and insufficient use of the concept in MSP is also recognised by the EC in review and guidance documents on the implementation of the EU GI strategy. To our knowledge, the testing of marine GI mapping performed by the Pan Baltic Scope project was the first such exercise in the EU at the sea basin level. We have aggregated various spatial data layers on the distribution of benthic habitats, birds and fish in order to identify the areas of high ecological value and ecosystem service supply potential, which thus form the marine GI. However, the proposed methodology needs to be developed further to include a connectivity analysis, a more comprehensive ecosystem service assessment and an improvement in input data quality.

The Pan Baltic Scope approach to GI mapping can contribute towards a holistic perspective, linking MSP to the maintenance of biodiversity and environmental management. Both MSP and the development of the MPA network relates to marine GI. In a longer perspective it would be possible to link these processes with conservation and development targets. MSP has potential to contribute to such targets and GI mapping is one step in that direction. To reach this, further dialogue which links planning and management is needed, as well as common development of knowledge of the Baltic ecosystems.