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Green Infrastructure Concept for MSP and Its Application Within Pan Baltic Scope Project

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

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Abbreviations

ABBREVIATIONS	SPECIFICATION	COMMENT
BEF	Baltic Environmental Forum	Non-governmental organisation
BONUS BASMATI	Baltic Sea Maritime Spatial Planning for Sustainable Ecosystem Services	Project funded by the EU BONUS programme focusing on maritime spatial planning and marine and coastal ecosystem services
BSII	Baltic Sea Impact index	Developed by the HELCOM holistic assessment published in 2010
CBD	Convention on Biological Diversity	United Nations convention to protect and promote biological diversity
CICES	Common International Classification of Ecosystem Services	System developed by the EEA, see http://cices.eu/
EBSAs	Ecologically or Biologically Significant Marine Areas	Defined according to the scientific criteria adopted by the Conference of the Parties to the Convention on Biological Diversity (COP 9)
EC	European Commission	European Union executive
EEA	European Environmental Agency	European Union agency
EECONET	European ecological network	Pan-European approach to preservation of the natural heritage of Europe developed by Dutch Government
EFH	Essential fish habitats	Areas defined as essential for certain fish species
ES	Ecosystem services	The contributions of ecosystem structure and function to human well-being
EU	European Union	
GI	Green Infrastructure	Network of natural and semi-natural areas
HELCOM	Helsinki Commission	Environmental Intergovernmental Organisation
HELCOM HOLAS II	HELCOM Second Holistic Assessment of the Ecosystem Health of the Baltic Sea	HELCOM project
HELCOM-HUB	HELCOM Underwater biotope and habitat classification system	Developed as a part of the HELCOM Red List project
JRC	Joint Research Centre	EC science and knowledge service
LIAE	Latvian Institute of Aquatic Ecology	
MAES	Mapping and assessment of ecosystems and their services	EC working group for implementation of Task 5 of the EU Biodiversity Strategy 2020
MOSAIC	Framework for marine conservation values and ecological coherent networks	Developed by AquaBiota on behalf of the Swedish Agency for Marine and Water Management
MPAs	Marine protected areas	Marine conservation area, include national park, NATURA 2000, reserves etc.
MSP	Maritime spatial plan/planning	
NGOs	Non-governmental organisations	
OSPAR	Convention for the Protection of the Marine Environment of the North-East Atlantic	Legal instrument guiding international cooperation for the protection of the marine environment of the North-East Atlantic
PEEN	Pan-European ecological network	Initiative for implementation of the pan European biological and landscape diversity strategy (PEBDLS) under the auspices of the Council of Europe.
SEA	Strategic Environmental Assessment	A systematic decision support process to ensure that environmental aspects are considered effectively in policy, plan and program making
UN	United Nations	
VASAB	Vision & Strategies Around the Baltic Sea	An intergovernmental multilateral co-operation of 11 countries of the Baltic Sea Region in spatial planning and development
VELMU	The Finnish Inventory Programme for the Underwater Marine Environment	

Green Infrastructure

Introduction

Green Infrastructure (GI) is a relatively new concept with great potential for enhancing the ecosystem-based approach to spatial planning. The concept is rather well established in urban as well as regional planning of terrestrial areas, while its application in maritime spatial planning (MSP) is a novelty. To our knowledge, there is no established methodology or pool of expertise in the planning of marine GI. However, with growing interest and knowledge in marine ecosystem services, also the need for planning marine GI is recognised. This approach allows to identify ecological hot-spot areas essential for ensuring resilience of the marine ecosystem and delivery of a wide range of ecosystem services essential for human well-being, which might not be included in the network of marine protected areas, but are respected while defining conditions for the use of the sea within the MSP process.

The Pan Baltic Scope project aims to develop tools and approaches at the pan-Baltic level in order to contribute to coherent maritime spatial plans in the Baltic Sea Region, including implementation of an ecosystem-based approach, cumulative impact assessment, GI planning and socio-economic analysis. The Activity 1.2.4. is devoted to Green Infrastructure and involves the following tasks:

- To outline the concept of 'green infrastructure' by utilising 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);
- To collect feedback on the draft concept from the HELCOM-VASAB MSP Working Group and HELCOM State and Conservation Working Group.

In this document, we give an overview of the concept of GI, its existing definitions and policy context, as well as explore existing approaches to GI mapping. Further, we propose a Pan Baltic Scope approach to marine GI mapping, in which we describe the suggested components of marine GI, the assessment criteria and available data sets for GI mapping at the Baltic Sea scale. Finally, we draw conclusions 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.

1. Background: What is Green Infrastructure?

Infrastructure is usually defined as *all elements of interrelated system that provides goods and services essential for enabling or enhancing societal living conditions*[1]. Traditionally, infrastructure was understood as human-made assets which generate the benefits of welfare and distribute them to society. However, since 1980s scientists have suggested that ecosystems should also be considered as a type of infrastructure. The basis for such an assumption is the fact that a healthy ecosystem, besides maintaining biodiversity, can provide goods and services to humans, some of which are consumed directly, while others bring benefits to society only in interaction with human-made infrastructure[2]. Thus, Green Infrastructure (GI) is directly related to the concept of **ecosystem services**, which can be defined as "*contributions of ecosystem structure and function (in combination with other inputs) to human well-being*"[3].

The concept of GI has become popular in the urban context, where it refers to a patchwork of green areas providing habitats, flood protection, cleaner air, recreation or, at site scale, to specific nature-based solutions (e.g. bio-infiltration of stormwater, green roofs etc.). Now it is gaining importance for assessing the network of natural or semi-natural areas at regional, national and even Pan-European scale.

In 2013, the European Commission broadened the concept of GI, defining it as a 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."[4] As noted by Liquete et al. (2015)[5] this definition highlights three important aspects: i) the network of areas; ii) the component of planning and management; and iii) the concept of ecosystem services, which incorporates the notions of ecological connectivity, conservation and multi-functionality.

Network of areas of high ecological value

The concept of GI is rooted in the theories of landscape-ecology and **ecological networks**, which were elaborated by scientists mostly during second half of the 20th century[6]. The main components of ecological networks include: core areas (i.e. central nodes in the network), ecological corridors (i.e. continuous connections between the nodes), stepping stones (i.e. non-continuous corridors), buffer zones (i.e. barriers between natural and anthropogenic areas), and restoration areas (i.e. anthropogenic areas that are being managed to make them more natural).[7] [8] The **objective for designing and managing ecological networks is to preserve**

1 Fulmer J.E., 2009. What in the world is infrastructure? Infrastructure Investor 9, 30–32.
2 da Silva J.M.C. & Wheeler E. (2017). Ecosystems as infrastructure. Perspectives in ecology and conservation. 15: 32-35
3 Burkhard et al., 2012. Solutions for sustaining natural capital and ecosystem services. Ecological Indicators, 21: 1 – 6.
4 EC, 2013. Green infrastructure (GI) – Enhancing Europe's Natural Capital. COM(2013)249.
5 Liquete., et al. 2015. Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. Environmental Science and Policy, 54, 268–280.
6 Forman, R.T. T. & Godron M. 1986. Landscape Ecology. John Wiley and Sons (New York).
7 Sepp, K., Kaasik, A. (Eds.), 2002. Development of National Ecological Networks in the Baltic Countries in the Framework of Pan-European Ecological Network. IUCN European Programme, Warsaw, Poland. International Union for Conservation of Nature (IUCN), Gland, Switzerland. 183 pp.
8 Mander et al., 2018. Green and brown infrastructures support a landscape-level implementation of ecological engineering. Ecological Engineering 120: 23–35.

biological diversity through the interconnectivity among the network's physical elements within the landscape[9]. In Europe the concept of ecological networks has been applied to terrestrial areas since 1990s, including such initiatives as the European ecological network (EECONET) and the Pan-European ecological network (PEEN), followed by the legally binding requirements of the EU Habitats Directive for establishment of Natura 2000 network, extending it to include marine areas.

The crucial aspect for maintaining ecological networks is **connectivity**, which in ecological terms refers to the possibilities of dispersion of individuals from the patches of source habitat to destination patches[10]. Connectivity can be described by its structural component (i.e. the physical characteristics of the landscape, such as topography/bathymetry, morphology, etc.) as well as its functional component (i.e. ecological characteristics determining how individuals and populations move through this space)[11 12]. In the context of ecological networks and GI, the structural connectivity component is formed by core areas of high ecological value and corridors or structures enabling connections between them. The level of connectivity can be measured by the dispersal ability and habitat requirements of species; hence it strongly depends on what species are considered and how the environment modulates the connectivity patterns (e.g. through the fields of current velocity, salinity, temperature and light).

Concept of ecosystem services

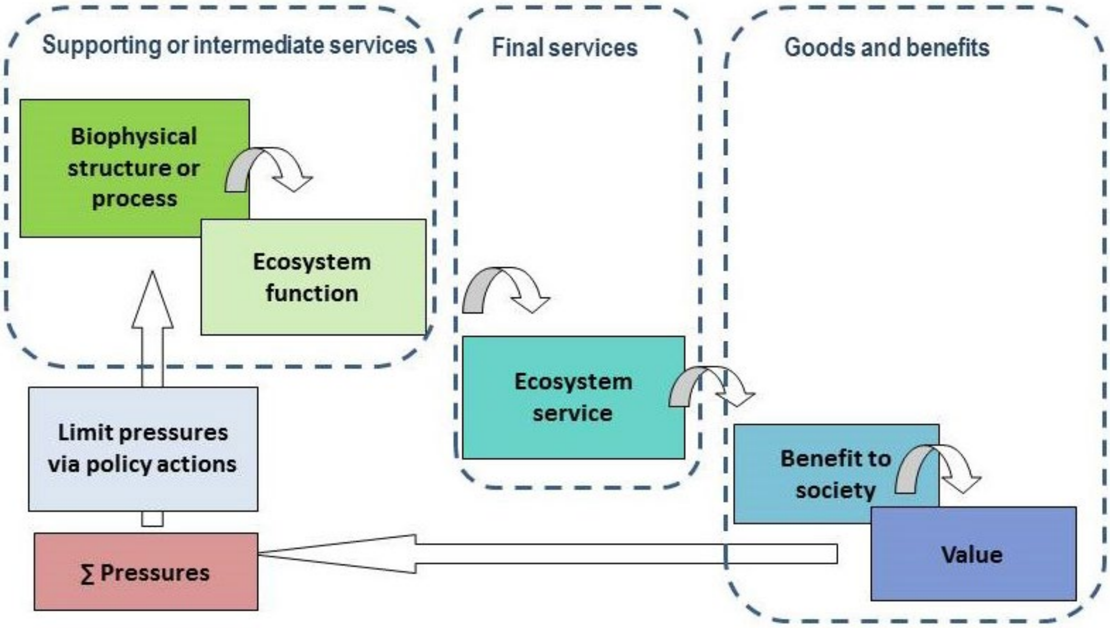
The GI concept includes biodiversity conservation aspects encompassed in the concept of ecological networks described above, at the same time addresses the role of the network in the delivery of a wide range of ecosystem services. Thus, **the emphasis of the GI concept is on multifunctionality of ecosystems** in providing benefits for both humans and nature. Therefore, any efforts in mapping or designing GI should also include assessment of its contribution to ecosystem service supply. However, in doing this, the complexity of the concept of ecosystem service shall be considered.

The interrelations between the ecosystem and human well-being are illustrated by the so called 'cascade model', proposed by Haines-Young and Potschin (2010)[13] and further refined by La Notte et al. (2017)[14]. According to this model, ecosystems are linked stepwise to human well-being through the flow of ecosystem services (Figure 1). The ecosystem is characterised by its biophysical structure and ecological processes (dynamics and interactions forming the ecological system, e.g. primary production). The ecosystem features (structure and functions) which underpin the capacity of the ecosystem to deliver an ecosystem service are called 'supporting' or 'intermediate' services. The 'final' ecosystem services are those which are then realised into direct benefits, contributing to human well-being (e.g. food, health, safety and prosperity). The possibility to map and assess ecosystem service supply is usually limited by the data and knowledge available. In general, there is a critical knowledge base on different nature assets which provide ecosystem services. However, we often lack knowledge on how to derive the value of those services (flows) from the given ecosystem features (structures). Therefore, rather than mapping the realised (i.e. final) ecosystem

9 Jongman et al., 2011. The pan European ecological network: "PEEN". Landscape Ecology, 26: 311–326.
10 Kukkala A.S. & Moilanen A., 2017. Ecosystem services and connectivity in spatial conservation prioritization. Landscape Ecology, 32:5-14.
11 Rudnick D.A., et al. 2012. The role of landscape connectivity in planning and implementing conservation and restoration priorities. Issues in Ecology, 16:1-23.
12 Rega C., 2019. Towards and Effective Implementation of Green Infrastructure in Rural Areas. Challenges and Options for a Substantial Integration with Spatial Planning. In: Gottero E. (Eds.). Agrourbanism. Tools for Governance and Planning of Agrarian Landscape. Springer Nature Switzerland AG., p. 73-85.
13 Haines-Young, R., Potschin M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D.G & C.L.J. Frid (eds.): Ecosystem Ecology: A New Synthesis. Cambridge University Press, British Ecological Society, pp. 110-139.
14 La Notte et al., 2017. Ecosystem services classification: A systems ecology perspective of the cascade framework. Ecological Indicators, 74:392–402.

services, it is often easier to map ecosystem structures, which can be then interpreted in relation to their potential to supply an ecosystem service.

Fig. 1: The cascade model (adapted from Potschin-Young, 2018) [15]



Planning contexts

According to the EC definition provided above, GI is envisaged as a *"strategically planned network".* This calls for a strategic approach and human action in designing such a network. The strategic approach allows the 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.

Furthermore, as defined by the EC Communication (2013), "GI is based on the principle that the protection and enhancement of nature and natural processes, and the many benefits human society gets from nature, are consciously integrated into spatial planning and territorial development." GI planning is suggested as "a policy tool that stands to improve human well-being through its environmental, social and economic values, based on the multifunctional use of ecosystems." [16] Spatial planning is also recognised as the most effective way for developing GI, which at a strategic level can help to[17]:

- locate the best places for habitat enhancement/restoration projects for reconnecting healthy ecosystems or improving connectivity between protected areas;
- guide developments away from particularly sensitive nature areas to more robust areas where the development projects can contribute to restoring or recreating GI features as part of the development proposal;

15 Potschin-Young et al., 2018. Understanding the role of Conceptual Frameworks: Reading the Ecosystem Service Cascade. Ecosystem Services, 29:428-440.
16 Vallecilloa et al., 2018. Spatial alternatives for Green Infrastructure planning across the EU: An ecosystem service perspective. Landscape and Urban Planning, 174: 41-54.
17 European Union, 2013. Building a Green Infrastructure for Europe, http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_broc.pdf

- identify multifunctional zones, where compatible land/sea uses that support maintenance of healthy ecosystems are favoured over more destructive single-focus developments.

Thus, through integration with spatial planning, the GI concept becomes a cornerstone in the implementation of an ecosystem-based approach to the management of human activities. According to the definition of the Convention on Biological Diversity (CDB) the ecosystem-based approach is understood as "a strategy for the integrated management of land, water and living resources that promotes conservation and sustainable use in an equitable way." The GI concept helps in the implementation of an ecosystem-based approach by addressing the complexity of ecosystems and their interactions with social and economic systems.[18]

Policy context

The conservation and development of GI is acknowledged as one of the priorities of EU policies. It is directly targeted by the EU Biodiversity Strategy to 2020[19], as well as addressed in other EU policies, e.g. the Roadmap to a Resource Efficient Europe[20], the Commission's proposals for the Cohesion Fund and the European Regional Development Fund[21], the Common Agricultural Policy[22].

The EU Biodiversity Strategy's target 2 requires that "by 2020, ecosystems and their services are maintained and enhanced by establishing green infrastructure and restoring at least 15% of degraded ecosystems." Action 6 of the Strategy is setting priorities to restore and promote the use of green infrastructure, including a commitment of the Commission to develop "a Green Infrastructure Strategy by 2012 to promote the deployment of green infrastructure in the EU in urban and rural areas, including through incentives to encourage up-front investments in green infrastructure projects and the maintenance of ecosystem services, for example through better targeted use of EU funding streams and Public Private Partnerships."

As one of the key steps towards the implementation of the EU Biodiversity Strategy to 2020, the EC has adopted an **EU-wide strategy promoting investments in green infrastructure**. The strategy promotes the deployment of green infrastructure across Europe as well as the development of a Trans-European Network for Green Infrastructure in Europe, the so-called TEN-G, equivalent to the existing networks for transport, energy and ICT, which should enhance the health and wellbeing of EU citizens, provide jobs, and boost the economy.

The EC Communication on Green Infrastructure [23], published on 6 May 2013, clarifies the meaning of the GI concept and describes its contribution to the EU policies (i.e. regional policy, climate change and disaster risk management, natural capital and nature conservation). With regard to the marine environment, the EC Communication notes that "*GI can help put the current strategies on marine spatial planning and integrated coastal zone management into practice, in particular the strategies for sustainably managing coastal zones and making coastal defences more efficient.*" It also states that further development of blue carbon approaches, beneficial for fish stocks, can profit from the application of GI principles to promote multiple ecosystem services in the marine environment.

18 Pan Baltic Scope, 2019. An Analytical Framework to advance the Ecosystem-Based Approach in MSP.
19 COM (2011) 244 final, http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0244&from=EN
20 COM (2011) 571 final, http://ec.europa.eu/environment/resource_efficiency/pdf/com2011_571.pdf
21 COM (2011) 612 final/2, http://www.espa.gr/elibrary/Cohesion_Fund_2014_2020.pdf; COM (2011) 614 final, http://www.esparama.lt/es_parama_pletra/failai/fm/failai/ES_paramos_ateitis/20111018_ERDF_proposal_en.pdf
22 COM (2010) 672 final, http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2010:0672:FIN:en:PDF Regulations 1305/2013, 1306/2013, 1307/2013 and 1308/2013.
23 COM(2013)249. In http://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF

Furthermore, the EC Communication outlines the EU strategy on GI, stating what needs to be done to encourage the development of GI, e.g.:

- **integrating GI into the key policy areas** and ensuring that it becomes a standard part of spatial planning and territorial development;
- **improving the information, knowledge base and reliable data** on: the extent and conditions of ecosystems and services they provide; understanding the links between the biodiversity and conditions of an ecosystem (vitality, resilience and productivity) and between the conditions of an ecosystem and its capacity to deliver ecosystem services; the valuation of ecosystem services, in particular the social, health and security/resilience benefits of GI solutions;
- **providing financial support** for GI projects and setting up innovative funding mechanisms for encouraging GI development across the EU.

The Communication stresses that many geographical features (e.g. mountain ranges, river basins, forests) go beyond national boundaries, forming a part of the EU's shared natural heritage, which requires coordinated and joined-up actions to manage it. The same applies to marine areas, which form interconnected ecosystems and require co-ordinated approach to GI planning and management.

The EC Guidance on a strategic framework for further supporting the deployment of EU-level green and blue infrastructure was published in May 2019. The objective of the guidance is to encourage scaling-up of investments in GI and stimulating a more strategic and integrated approach to deployment of GI at EU level. The guidance provides criteria to identify EU-level green and blue infrastructure projects as well as describes the relevant EU supporting tools and instruments.[24] The proposed criteria for EU-level GI projects include the following: contribution towards the conservation and/or enhancement of multiple ecosystem services at a significant scale; contribution to the goals of the Birds and Habitats Directives; and a strategic approach and EU-level impact.

Following the objectives set by the EU Biodiversity Strategy 2020 as well as the EC Communication on Green Infrastructure, several initiatives on GI mapping and strategic planning have been launched, ranging from local scale projects up to EU level studies (e.g. by Liquete et al. 2015, Vallecilloa et al., 2018 et al.). Though, as noted by the **Joint Research Centre (JRC) report on "Strategic Green Infrastructure and Ecosystem Restoration"** (2019), *"There is a significant gap in knowledge regarding the deployment of GI in the marine environment and regarding the nexus between blue-green infrastructure. 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."*[25]

In the Baltic Sea region, the **HELCOM-VASAB Maritime Spatial Planning working group** addressed the topic of GI at its 15th meeting held in Warsaw, Poland, 7-8 November 2017, by preparing a background document on "Green infrastructure"/ "Blue corridors". The document outlines the definitions, functions and features of GI, and highlights its applicability to the marine ecosystem. The following features forming GI were noted: nature-rich areas (functioning as core and hubs for green infrastructure, e.g. protected areas like Natura 2000 sites and Marine Protected Areas); other wildlife and natural areas; areas of high value for biodiversity and ecosystem health outside protected areas (e.g. EBSAs); ecological corridors

24 EC, 2019. Guidance on a strategic framework for further supporting the deployment of EU-level green and blue infrastructure.
25 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.

(i.e. blue corridors) and ecological buffer zones, or actions such as restoration of landscape and ecosystems. The background document states that the HELCOM-VASAB MSP working group (work plan paragraph 3.3) calls to "investigate the possible regional development of concepts such as green infrastructure, blue corridors etc." with the aim of producing a draft regional concept of green infrastructure by the end of 2019. It also indicates that the Pan Baltic Scope project is going to test and further develop the concept of GI for the Baltic Sea region.

Following the concept outlined in the EC Communication (2013), the GI shall be formed by a network of natural or semi-natural areas, designed and managed to deliver a wide range of ecosystem services. Thus, for the mapping of GI the ecological or nature conservation value of the areas as well as their potential to deliver ecosystem services shall be assessed.

2. Existing approaches to GI mapping

Within the Pan Baltic Scope, we have surveyed the existing approaches, in the Baltic Sea Region and beyond (both marine and terrestrial realm), to assessing the ecological value of marine areas and the potential of these areas to provide ecosystem services. In total, 19 existing national-scale attempts at mapping ecologically valuable or sensitive areas were identified. These cases represent a considerable variety of approaches towards determining the value of the area (table 1). 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. The feature assessed in most of the cases was benthic habitats, followed by areas important for bird species. The most often used criteria for assessing the ecological value were biodiversity, rarity and importance for threatened species/habitats, as well as aggregation (i.e. areas important for particular species groups). Only eight cases considered the special importance of the area for life-history stages of species, while six of them considered the productivity of the area.

In the following sections we present some examples of different approaches which are or can be applied in marine GI mapping.

Table 1: Existing national attempts at mapping ecologically valuable or sensitive areas

Country	Title of the map	Institutions involved
Estonia	Aggregated environmental value	Estonian Marine Institute
	Aggregated benthic sensitivity	Estonian Marine Institute
Latvia	Map of biologically valuable areas	Latvian Institute of Aquatic Ecology
	Maps of marine ecosystem service supply	Latvian Institute of Aquatic Ecology Baltic Environmental Forum
Poland	Map of valuable natural areas	Marine Institute of Gdansk
	Map of the distribution of animal species (fish, birds, mammals)	Marine Institute of Gdansk
	Map of the distribution of birds and natural habitats	Maritime Office of Szczecin
	Natural conditions of spatial planning in Polish sea areas including the Natura 2000 network - Valorisation of natural habitats of selected fragments of Polish sea areas	Several research institutes: Instytut Oceanologii PAN, Instytut Oceanografii UG, Instytut Morski w Gdańsku, Morski Instytut Rybacki oraz Państwowy Instytut Geologiczny
Germany	Nationwide Green Infrastructure Concept	Federal Agency for Nature Conservation
	Hotspots of biodiversity in Germany	Federal Agency for Nature Conservation
	Marine monitoring maps for seabirds and porpoise	Federal Agency for Nature Conservation
	Important areas for benthos, avifauna, marine mammals	IOW, FTZ, ITAW
Sweden	Green Map III	The Swedish Agency for Marine and Water Management
	MOSAIC	The Swedish Agency for Marine and Water Management
Finland	Conservation value (VELMU data and modelling)	Finnish Environment Institute
	Plan4Blue: Marine and Coastal Vulnerability profile	Finnish Environment Institute & Estonian Marine Institute
Åland	Map of ecological valuable areas	Åland Government, Åbo Akademi University and The Geological Survey of Finland
	Map of sensitive marine areas	Åland Government + other institutions
	Green infrastructure map	Åland Government

2.1. Mapping of GI based on network of protected areas or other ecologically significant areas

The existing network of protected areas, including Natura 2000 sites as well as other areas defined as significant in terms of biodiversity conservation, can serve as the backbone or core areas of GI. However, the establishment of GI in marine areas should not be limited to the features protected by the EU Habitats and Birds Directives. Rather, the definition and delineation of marine GI should encompass various criteria which characterise the marine ecosystem, as well as the services and benefits it delivers to society. Other features of importance for GI are the coherence and connectivity of the network.

2.1.1. German approach to GI mapping

In 2017, Germany developed the map of its nationwide GI Concept, which covers areas of high biodiversity value. They include national parks, Natura 2000 sites, nature conservation areas, national nature monuments, wetland, dryland, near-natural woodland habitat networks (core spaces), Ramsar sites, HELCOM and OSPAR marine protected areas, biosphere reserves (core and buffer zones), as well as areas eligible for funding under large-scale nature conservation projects, nationally significant axes/corridors for ecological networks (wetland, dryland and near-natural woodland habitats, large mammals), Green Belt, peatlands (on account of their significance for climate protection and as soils for carbon storage), Natura 2000 sites in the EEZ, as well as active and inactive floodplains (Figure 2). This mapping exercise was not based on the calculation of aggregated ecological value but rather represents all components of nature conservation value or the ones regarded as representing the nationwide Green Infrastructure.

Fig. 2: Nationwide GI Concept in Germany. Source: Federal Agency for Nature Conservation (BfN) (2017).

The German Federal Green Infrastructure Concept provides a foundation on which nature conservation and landscape management authorities will be able to draw up technical papers that can be applied in all relevant areas of policymaking. It bundles the technical nature conservation concepts that are in place at the federal level and takes up the European Commission's initiative on development of GI.

2.1.2. Options for applying existing networks of biologically valuable marine areas for mapping GI in the Baltic Sea: HELCOM MPAs and EBSAs

One option in order to identify the core areas of GI in the Baltic Sea could be based on the network of the **HELCOM MPAs,** which integrates marine Natura 2000 sites. By 2016, the area of MPAs in the Baltic Sea had reached 12% (Figure 3). However, during the discussions of the Pan Baltic Scope project expert meetings on GI, it was acknowledged that the existing network of the Baltic MPAs might not be sufficient for defining the core areas of GI due to the fact that there was very limited knowledge on the species and habitat distribution at the time when the sites for the MPAs were proposed.

Another option for identifying the core areas of ecological value could be based on the concept of **Ecologically or Biologically Significant Marine Areas (EBSAs)**, developed within the framework of the UN Convention on Biological Diversity (CBD). EBSAs are defined as "special areas in the ocean that serve important purposes, in one way or another, to support the healthy functioning of oceans and the many services that it provides." Hence, the EBSAs do not require legal designation like MPAs and can cover much wider areas not limited to distribution of protected species and habitats. The criteria for selecting EBSAs include: i) uniqueness or rarity; ii) special importance for life-history stages of species; iii) importance for threatened, endangered or declining species and/or habitats; iv) vulnerability, fragility, sensitivity, or slow recovery; v) biological productivity; vi) biological diversity; and vii) naturalness. The application of the EBSA criteria is a scientific and technical exercise carried out within an expert workshop. The first EBSA Baltic workshop was organised in spring 2018 by the CBD and HELCOM Secretariats and involved ca. thirty experts representing 7 HELCOM countries and NGOs. As result of this workshop, proposals on the Baltic Sea EBSAs were developed (Figure 4). The proposal was adopted by the UN Biodiversity (CBD) at COP 14 in November 2018.

Fig. 3. MPA network in the Baltic Sea (Source: HELCOM 2018[26])

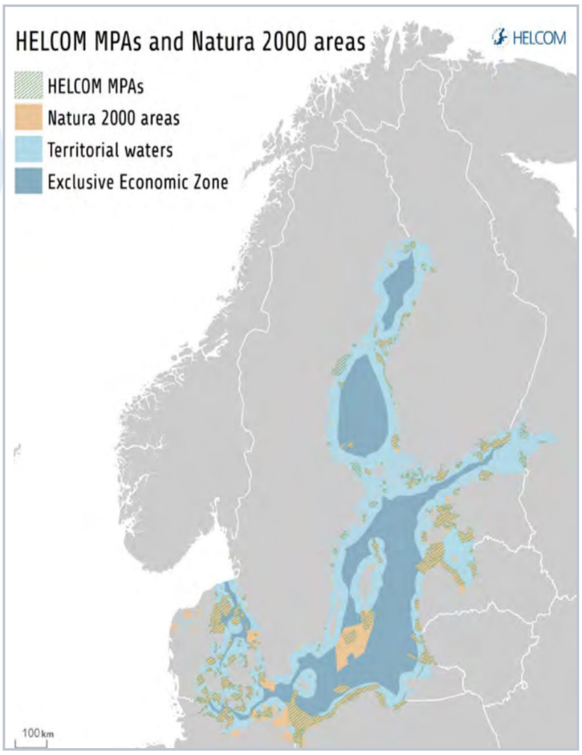
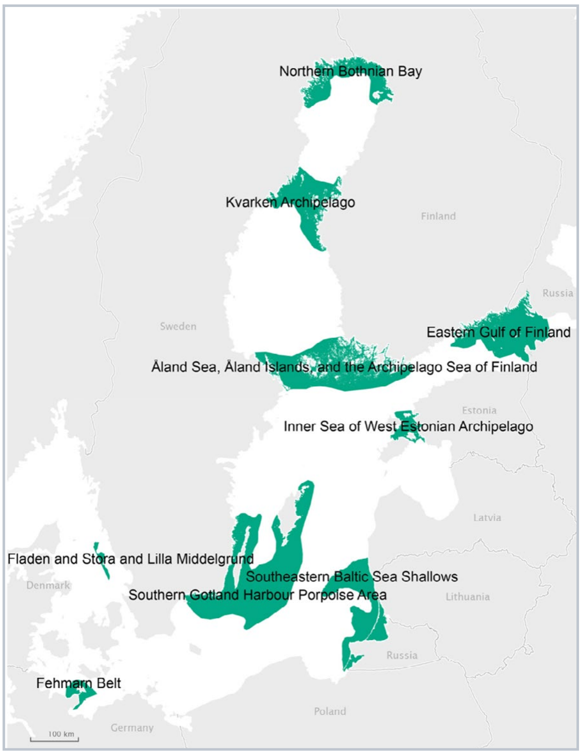


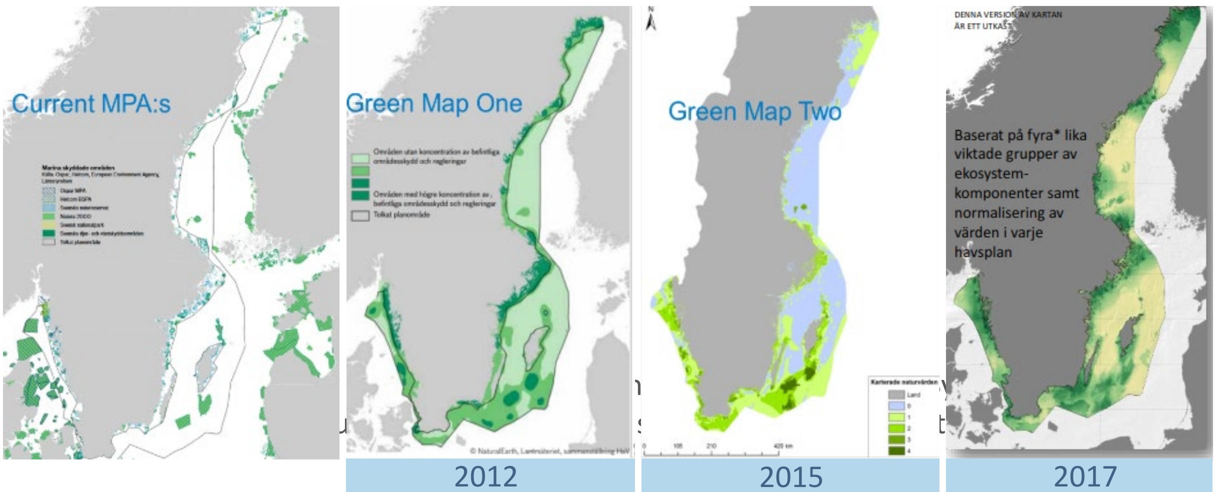
Fig. 4. Outcome of the Baltic Sea EBSA workshop (source: HELCOM, 2018[27])



2.2. Mapping of marine GI based on aggregation of data on various biotic features: Swedish approach of Green Map and MOSAIC

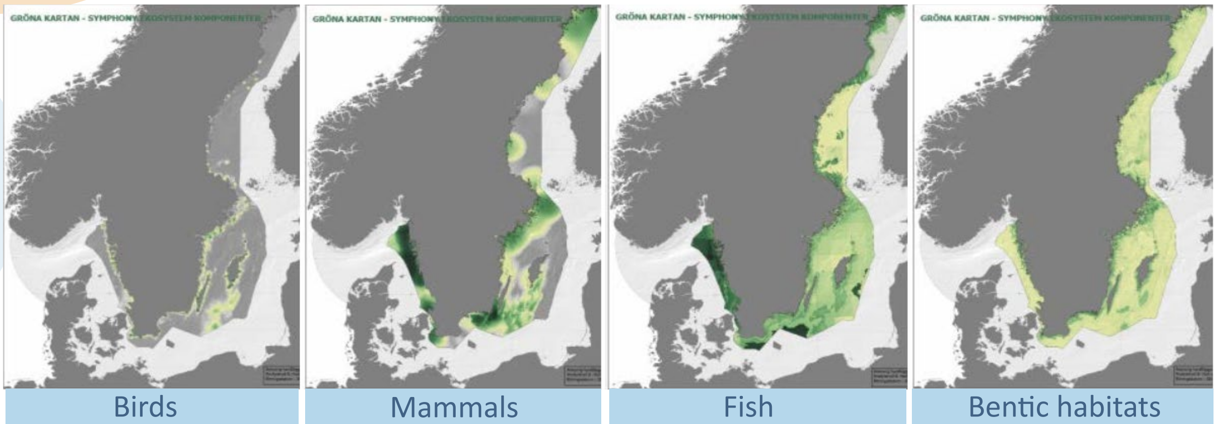
The Swedish Green Map was developed as an input to the national MSP process. Starting from 2012, three versions of the map were developed, increasing the data accuracy (Figure 5). The aim of all the green map versions has been to make aggregated spatial information on marine nature values available for consideration in MSP. The first green map was based on any data which could indicate a higher nature value. Starting with the second green map a bottom up approach has been applied which uses biological data or modelled representations to identify areas with high nature value.

Fig. 5. History of the Green map development of the Swedish marine waters. Source: Swedish Agency for Marine and Water Management



26 HELCOM, 2018. State of the Baltic Sea – Second HELCOM holistic assessment 2011-2016. Baltic Sea Environment Proceedings 155.
27 http://www.helcom.fi/new-ebsas-in-the-baltic-sea

Fig. 6. Biotic features included in the development of the Green map. Source: The Swedish Geological Survey



Both the second and the third green map have been used to identify areas in the MSP where special consideration has to be given to high nature values. These so called “n-areas” add a nature dimension to MSP in addition to the existing and planned Marine Protected Areas. They indicate that coexistence between nature and other sea uses is possible, while any harm to the listed nature values should be avoided.

MOSAIC is a Swedish framework for identifying marine nature values in viable and ecologically representative networks. It aims to support functional, ecosystem-based and adaptive spatial management with focus on marine GI, marine protected areas and marine spatial planning (Figures 7 and 8). The ecosystem components that MOSAIC has focused on are **biotic**, *i.e.* species, habitats, biotopes and groups of organisms that could be linked to a physical place. Examples: Eelgrass meadows (*Zostera marina*) ≥ 25 % coverage, wintering areas for Long-tailed ducks (*Clangula hyemalis*), high concentration areas of calving/mating of Porpoises (*Phocoena phocoena*) and Cod spawning grounds (*Gadus morhua*).

Fig. 7. Approach to developing MOSAIC with a more general preparatory part, laying the basis for regional or local identification of core areas and shaping a network of areas with high nature values

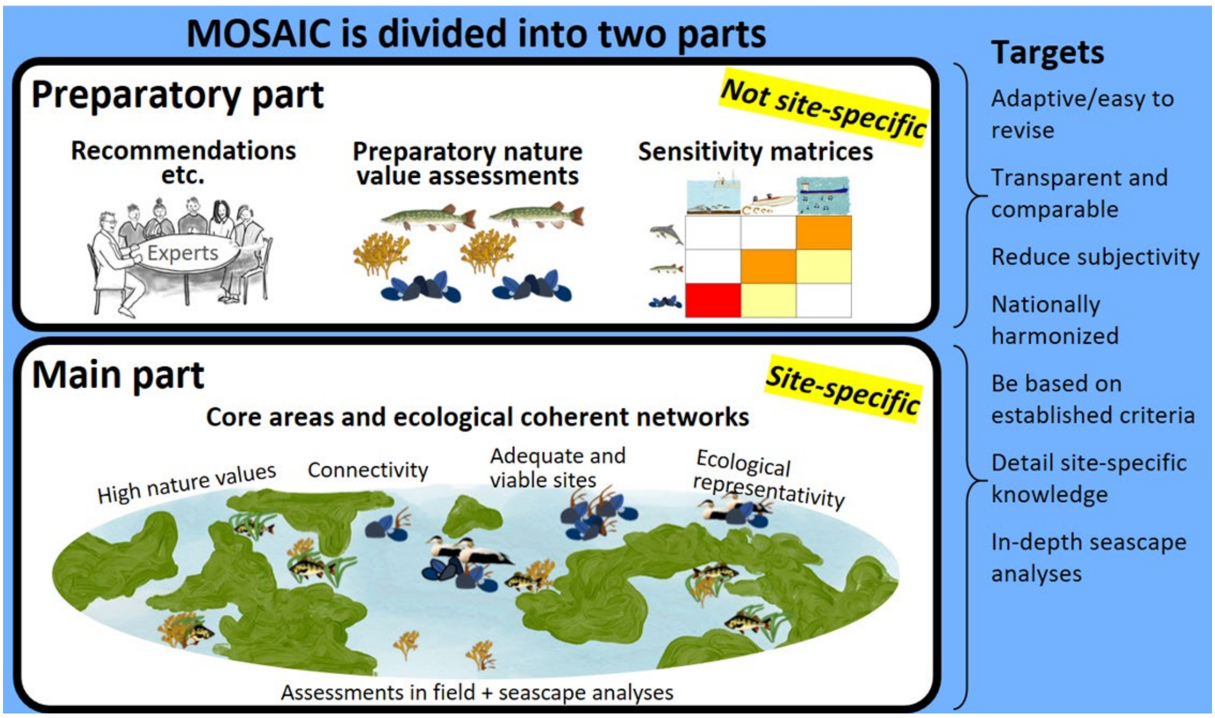
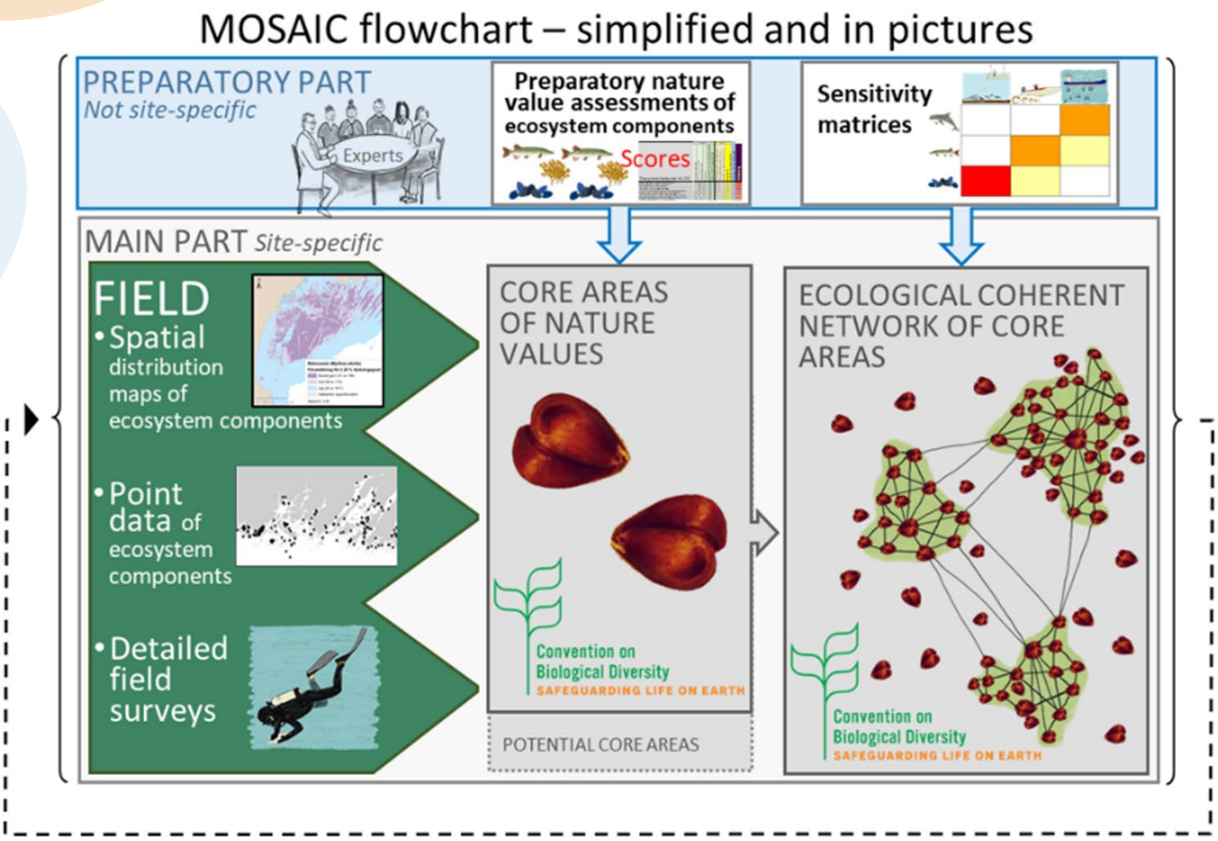
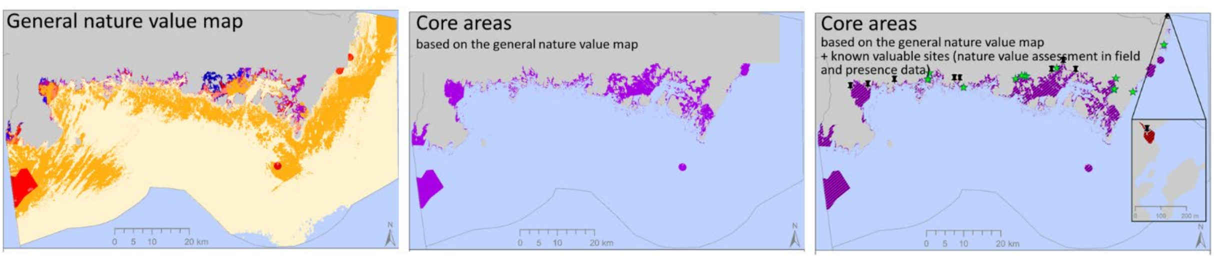


Fig. 8. MOSAIC flowchart in pictures



Within MOSAIC the site-specific assessment of nature value is based on all EBSA criteria. However, the preparatory nature value assessment focuses on the following criteria: biological diversity, importance for lifecycle history stages and ecological function as values for nature and indirect ecosystem services. The preparatory assessment also includes an optional step of adding a dimension with direct Ecosystem Services. Moreover, the threat status of the ecosystem components can be visualised. To further analyse and visualize GI, MOSAIC includes all CBD criteria for ecologically coherent networks. For instance, the criteria adequate and viable sites is partly analysed with the support of sensitivity matrices and the criteria ecological representativity is analysed based on many different biotic ecosystem components. The MOSAIC framework has partly been tested in the development of regional action plans for GI in Sweden and by a scientific cross-disciplinary study involving experts in both ecology and law (Figure 9).

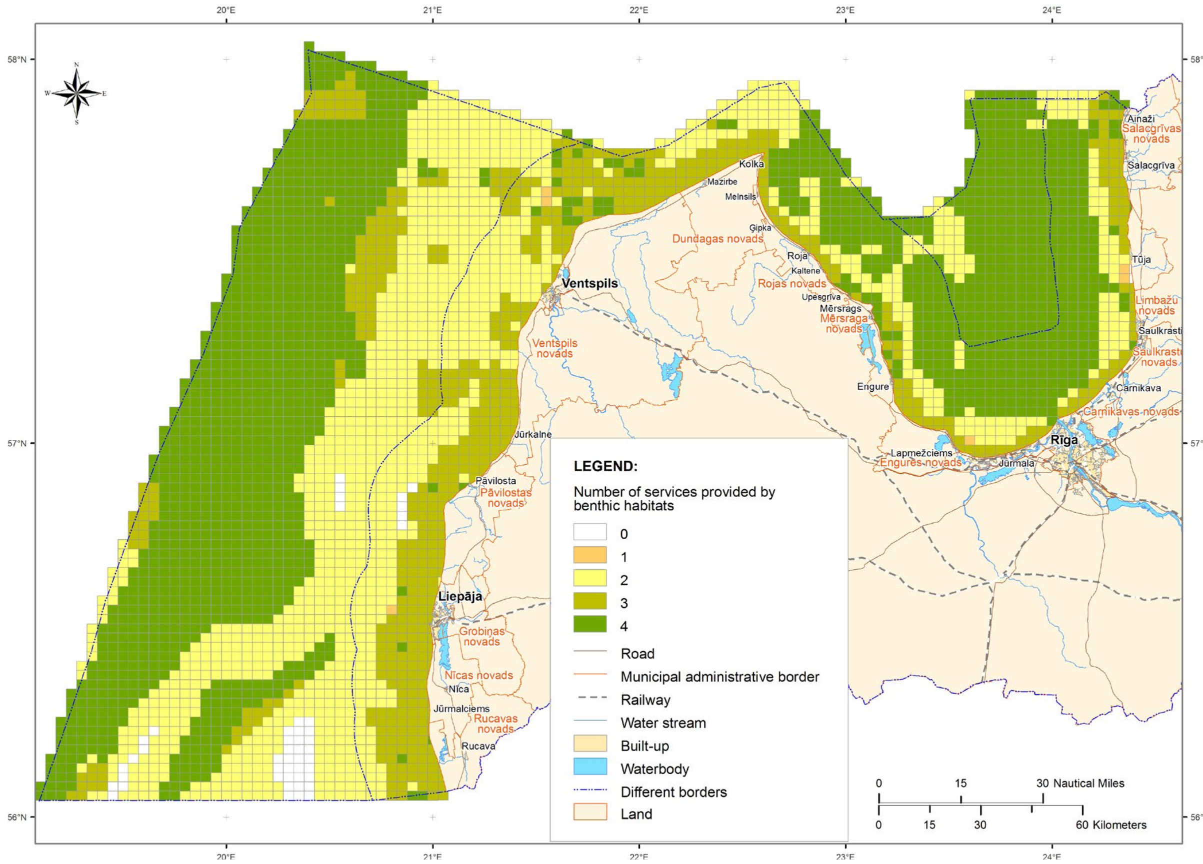
Fig. 9. Examples of maps produced with MOSAIC



2.3. Mapping potential supply of marine ecosystem services: Latvian approach

Biophysical mapping of selected ecosystem services was performed as an input for the Latvian Maritime Spatial Plan (MSP), developed in 2015-2016[28]. Experts identified the potential of benthic habitats to supply five services (*bioremediation, filtration of nutrients, maintaining of nursery populations and global climate regulation*). The process involved simple qualitative assessment (spreadsheet method) using a binary scale (i.e. 'yes/no'). The benthic habitat map, which was developed on the basis of the HELCOM-HUB classification system, was used as a proxy for mapping the potential distribution of ecosystem services. On the basis of expert assessment results, six maps of single regulating services were prepared, as well as a summary map with the number of identified services represented in each grid cell (Figure 10).

Fig. 10. Number of regulating and maintenance services provided by benthic habitats. Map developed by LIAE & BEF. Source: Ministry of the Environmental Protection and Regional Development of the Republic of Latvia, 2016



Quantitative assessment and mapping of a few provisioning and cultural services was possible using field data on service supply. To assess the potential supply of the provisioning service *algae and their outputs,* the area covered by red algae was mapped using field survey data as well as expert knowledge on habitat suitability for growth of the species. Another provisioning service, namely *fish for food*, was assessed using data from fishery log books on total landing of commercial species (sprat, herring, cod and flounder) for the period 2004–2013, calculated within the same grid cell. The cultural service *marine tourism and leisure possibilities at*

28 Veidemane K., Ruskule A., Strake S., Purina I., Aigars J., Sprukta S., Ustups D., Putnis I. & Klepers A. (2017) Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia, International Journal of Biodiversity Science, Ecosystem Services & Management, 13:1, 398-411.

the coast was assessed using a spatial multi-criteria analysis method, which combines four criteria: i) accessibility; ii) proximity to densely populated areas; iii) suitability of the area for a particular (niche) tourism or leisure activity; and iv) recreational use. The results from the ecosystem services mapping were applied to characterise the marine ecosystem as well as to assess the possible impacts of sea uses on ecosystem services supply as part of the Strategic Environmental Assessment (SEA).

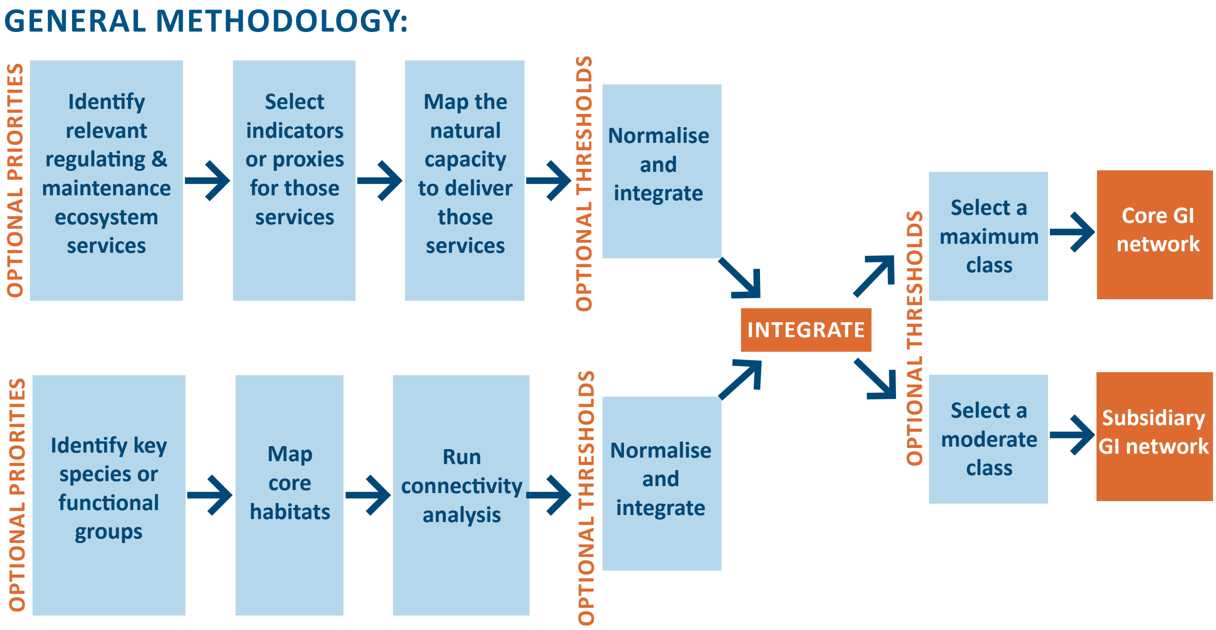
2.4. Mapping of GI based on ecosystem services and ecological networks: A Pan-European case study

The European Environmental Agency (EEA) has developed a comprehensive methodology for mapping multi-functional GI at European scale. It is based on the supply of ecosystem services as well as ecological networks formed by core habitats for target species and the connectivity between these habitats (published by Liquete et al., 2015)[29]. The methodology was tested within a continental case study covering the EU-27 territory, and focused on a landscape scale. However, it is applicable at different spatial scales for planning and policy implementation.

Following the definition of GI proposed by the EC Communication in 2013, the approach focuses on two crucial criteria for the identification of GI elements: i) multifunctionality linked to the provision of a variety of ecosystem services, and ii) the connectivity associated with the protection of ecological networks. The methodology involves the following steps (Figure 11):

- Quantification of the natural capacity to deliver ecosystem services
- Identification of essential core habitats and their connectivity analysis
- Normalization of original values of ecosystem service and core habitat & corridor assessment
- Integration of obtained results into a meaningful network of GI

Fig. 11. Methodology proposed by the EEA for mapping GI within a Pan-European case study (Liquete et al., 2015)



29 Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B., et al. (2015). Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. Environmental Science and Policy, 54, 268–280.

The first part of the assessment addresses the natural capacity of the area to deliver ecosystem services. Within the presented case study, eight regulating and maintenance services were selected, among them: air quality regulation, erosion protection, water flow regulation, coastal protection, pollination, maintenance of soil structure and quality, water purification and climate regulation. Different methods can be applied for mapping ecosystem services. They range from direct conversion of land use/ land cover maps as proxies for ecosystem service supply, through the compilation of local primary data or statistics, up to application of dynamic process-based models. Within the case study, proxies of biophysical process determining each ecosystem service were defined on the basis of published scientific models and results. The resulting maps were normalised reclassifying the ecosystem assessment data in five ranks, ranging from minimum (1) to maximum capacity (5).

The second part of the case study included identification of core and transitional habitats for key functional groups. As core habitats and functional groups are linked to species identity, the study involves identifying the most relevant species for the applied context.

In the European case study, the analysis focused on large mammals and on identifying large, dense forest patches as core habitats for key species, followed by analyses of habitat connectivity for sections of wildlife corridors between the identified patches.

The results from the habitat modelling were qualitative (i.e. showed the presence or absence of different kinds of habitats). However, for integration with the ecosystem service assessment, the results of habitat modelling had to be normalised using the same scale (ranks from 1 to 5). Thus, the following categories were assigned: maximum value (5) to the actual core habitats; high value (4) to wildlife corridors or transitional habitats among the core areas; moderate value (3) to other potential core areas or wildlife corridors; and minimum value (1) to the rest of the territory.

The normalised results of the ecosystem services assessment and habitat modelling were then integrated by the selection of maximum values, i.e. the value of the criterion with the highest score was assigned to each square kilometre. The core GI network included the areas which scored either the maximum value (5) for the capacity to deliver ecosystem services or actual core habits based on habitat modelling. The subsidiary GI network included the areas which scored value 4 for the capacity to deliver ecosystem services or the wildlife corridors or transitional habitats based on habitat modelling.

The authors conclude that the proposed methodology can be applied at any other location or scale. One of its main advantages is its flexibility to adjust the selection criteria by choosing appropriate ecosystem services or features essential for maintaining ecological networks.

3. Pan Baltic Scope approach for GI mapping

Following the objectives set in the project proposal, the task of the Pan Baltic Scope project (Activity 1.2.4) was to analyse previous and ongoing studies on the implementation of the GI concept and to develop a proposal for its application in the Baltic Sea, as well as to test the GI mapping by utilising the existing data sets. The existing interpretations of the GI concept and mapping approaches were presented and discussed during the 1st Pan Baltic Scope GI workshop, held in Riga, 29-30 May 2018. The participants of the meeting agreed on the overall **Pan Baltic Scope interpretation of the marine GI as a spatial network of ecologically valuable areas which are significant for:**

- maintenance of ecosystems' health and resilience;
- biodiversity conservation and;
- multiple delivery of ES essential for human well-being.

The approach proposed by the European Environmental Agency for GI mapping at EU level (described above in chapter 2.4) was acknowledged as suitable for the marine context and adaptable for developing the Pan Baltic Scope approach to GI mapping. This approach is also in line with the conceptual framework for planning strategic GI, published by the Joint Research Centre in 2019[30], which highlights two complimentary approaches: i) physical mapping of existing GI components, e.g. ecological networks, protected areas etc. and ii) ecosystem-service based mapping targeting delivery of multiple ecosystem services.

The Pan Baltic Scope approach to GI mapping includes 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.

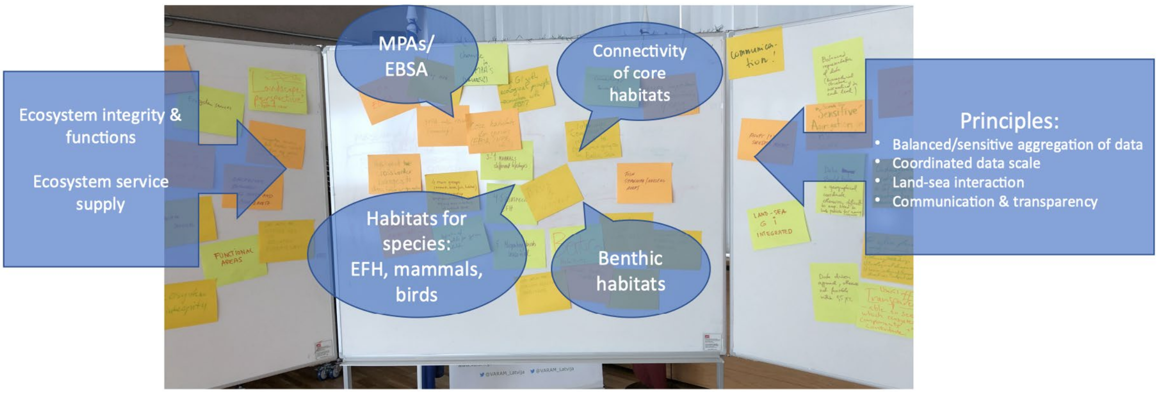
3.1. Identification of components forming marine GI

While GI forming elements or components can be relatively easily identified in terrestrial areas (e.g. core areas of ecological networks formed by patches of natural or semi-natural habitats and ecological corridors connecting them), this is usually not the case in marine setting, where habitats and species are much more interconnected and comparatively natural as opposed to terrestrial ecosystems. Therefore, a more elaborated approach is required to address the complexity of the marine ecosystem.

30 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.

Various components essential for marine GI were identified by the participants of the 1st Pan Baltic Scope GI workshop during the brainstorming exercise (Figure 12).

Fig. 12. Mind-map of GI components: results of the 1st GI workshop, Riga 29-30 May 2018



The proposals of the participants cover the following aspects:

1. Areas of high ecological value:

- The network of the existing marine protected areas (MPAs) and/or ecologically or biologically significant marine areas (EBSAs)
- Benthic habitats of high conservation value and/or core habitats for species e.g. (shallow vegetated habitats)
- Areas important for the main species groups (birds, fish, mammals) at different life stages, including essential fish habitats (EFH), e.g. spawning & nursery areas
- Ecosystem components vulnerable to human pressures
- Areas important for connectivity of the core habitats

2. Ecosystem integrity, functions and service supply:

- Ecosystem functions/supporting services
- Provisioning services (fish, algae, etc.)
- Regulating and maintenance services
- Cultural services (recreation, bird watching, education etc.)

Furthermore, several principles or conditions for GI mapping were identified, including:

- a balanced representation and sensible aggregation of data
- spatially referenced data
- coordinated data scale
- consideration for land-sea interaction
- clear communication and data transparency

The components of marine GI and their possible mapping approaches were further discussed at the 2nd GI workshop, held in Gothenburg, Sweden, 10-11 September 2018. An option for identifying areas of high ecological value based on existing network of MPAs or EBSAs was proposed. However, the participants of the meeting suggested that the existing networks of nature conservation areas and/or delineated areas of ecological value would not be sufficient as the basis for identifying GI core areas due to data limitations for MPAs/EBSAs and political context during the designation of such areas. It was agreed to apply a bottom-up approach by aggregating spatial data on the distribution of benthic habitats, birds, fish and mammals using the existing data sets.

Available data sets for mapping marine green infrastructure in BSR

As noted by the European Commission in the Communication on GI (2013), "consistent, reliable data are essential for effectively deploying GI. Information is needed about the extent and condition of ecosystems, the services they provide and the value of these services."

Mapping the areas of high ecological value and ecosystem service supply at the Baltic Sea scale requires regionally harmonised spatial data sets of the marine ecosystem components. Consistent data sets covering the whole Baltic Sea are available from the HELCOM Maps and Data services, as prepared within the HELCOM HOLAS II project (HELCOM 2018, Table 2).

Table 2. Ecosystem components included in the BSII tool of the HELCOM HOLAS II. Each ecosystem component layer name corresponds to the name of the map in the HELCOM Maps and Data Services

Ecosystem component group	Ecosystem component sub-group	EC layer
Pelagic habitats and species	Pelagic	Productive surface waters*
Benthic habitats and species	Marine landscapes	Availability of deep-water habitat, based on occurrence of H2S
		Infralittoral hard bottom
		Infralittoral sand
		Infralittoral mud
		Infralittoral mixed
		Circalittoral hard bottom
		Circalittoral sand
		Circalittoral mud
		Circalittoral mixed
	N2000 habitats (EU protected habitat types)	Sandbanks which are slightly covered by sea water at all time (1110)
		Estuaries (1130)
		Mudflats and sandflats not covered by seawater at low tide (1140)
		Coastal lagoons (1150)
		Large shallow inlets and bays (1160)
		Reefs (1170)
		Submarine structures made by leaking gas (1180)
		Baltic Esker Islands (UW parts, 1610)
		Boreal Baltic islets and small islands (UW parts, 1620)
	Key benthic species	Furcellaria lumbricalis
		Zostera marina
		Charophytes
		Mytilus spp.
		Fucus spp.

Essential fish habitats	Essential fish habitats	Cod spawning area**
		Baltic flounder spawning area [N]
		European flounder spawning area [N]
		Flounder nursery areas [N]
		Recruitment areas of herring [N]
		Recruitment areas of perch**
		Recruitment areas of pikeperch**
		Sprat spawning areas [N]
Bird habitats	Birds	Wintering seabirds
		Breeding seabird colonies
Mammal habitats	Mammal habitats	
Mobile species	Fish distribution and abundance*	Cod abundance
		Herring abundance
		Sprat abundance
	Bird distribution and abundance*	
	Mammal distribution and abundance*	Grey seal distribution
		Harbour seal distribution
		Ringed seal distribution
		Harbour porpoise distribution

*EC layers on pelagic habitats and the distribution or abundance of mobile species included in the BSII, but not in the GI concept as they are not detailed enough for addressing ecological value, or since they are not applicable to those ecosystem services included in the concept

** EC layers of the HOLAS II data set, which are replaced by new maps from the Pan Baltic Scope project

N The new layers added by the Pan Baltic Scope project and included in the GI concept

In table 2, the data sets marked with * or ** were not included in the Pan Baltic Scope GI concept due to poor suitability of the data for the intended purpose. In the case of fish data, the work was instead based on maps on essential fish habitats developed within Pan Baltic Scope. The essential fish habitat maps that were included represented spawning areas of cod, sprat, herring, European flounder, Baltic flounder, as well as recruitment areas of perch, pikeperch, and nursery areas of flounder (See document 3N-13 to State and Conservation 10-2019). Another component not included in the assessment is “productive surface waters”, because it covers the entire Baltic Sea and the services provided by the component would increase the overall value of the aggregated maps but would not reveal any spatial differences. The data set on mammal distribution has also been excluded due to the reasons described in chapter 3.2.3.

3.2. Mapping areas of high ecological value

3.2.1. Selection of criteria for assessing ecologically valuable areas

The ecological value of marine areas was assessed in relation to their importance for the maintenance of biodiversity. A survey carried out early in the Pan Baltic Scope project (Table 1) identified the criteria that have previously been applied in the Baltic Sea region for mapping ecologically significant areas, as summarized in Table 3.

Table 3: Criteria applied within the existing studies for mapping ecologically significant areas in the Baltic Sea (values in brackets indicate the number of studies in which the criteria were applied)

Criteria	Explanation
Biological diversity (14)	Area contains comparatively higher diversity of ecosystems, habitats, communities, or species, or has higher genetic diversity
Rarity (13)	Area contains either rare (occurs only in few locations) species, populations or communities, and/or rare or distinct, habitats or ecosystems or unusual geomorphological or oceanographic features
Aggregation (12)	Areas important for particular species groups, e.g. birds of fish species
Importance for threatened, endangered or declining species and/or habitats (12)	Area contains habitats for the survival and recovery of endangered, threatened, declining species or area with significant assemblages of such species; e.g. HD Annex I habitats; Annex II species; BD species
Vulnerability, fragility, sensitivity, or slow recovery (11)	Areas that contain a relatively high proportion of sensitive habitats, biotopes or species that are functionally fragile (highly susceptible to degradation or depletion by human activity or by natural events) or with slow recovery
Special importance for life-history stages of species (8)	Areas that are required for a population to survive and thrive
Proportional significance (8)	Coverage of benthic habitats
Naturalness (8)	Area with a comparatively higher degree of naturalness as a result of lack of or low level of human-induced disturbance or degradation
Uniqueness (7)	Area contains either unique ("the only one of its kind") or endemic species, populations or communities, and/or unique, distinct habitats or ecosystems; and/or unique geomorphological or oceanographic features
Biological productivity (6)	Area contains species, populations or communities with comparatively higher natural biological productivity

The relevant criteria for GI mapping within the Pan Baltic Scope Project were discussed and agreed during the 2nd GI workshop held in Gothenburg, Sweden, 10-11 September 2018. As the most feasible approach to delineate ecologically valuable areas, the experts suggested to assess the available regional spatial data sets on key ecosystem components (i.e. benthic habitats, birds, fish and mammals) against the criteria applied in the identification of ecologically or biologically significant marine areas (EBSAs), namely[31]:

- 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
- Biological productivity

31 Following the presentation of the Pan Baltic Scope marine GI concept to the HELCOM State & Conservation group on 7th May 2019, comments from Finland were received about the applicability of the EBSA criteria for assessment of the ecological value and scoring results. Finnish experts pointed out that the EBSA criteria have been developed for delineation of the areas fulfilling the criteria, whereas within the Pan Baltic Scope GI expert group has followed a different approach i.e. scoring ecological values based on their relevance in the particular EBSA criterion.

3.2.2. Methodology for mapping ecological value of marine areas

To obtain maps representing areas of high ecological value in the Baltic Sea, the different ecosystem components (Table 2) were assessed against the six criteria (see above). A matrix was developed to represent all possible combinations of ecosystem components and criteria. Value 1 was assigned to each combination where the ecosystem component was identified as relevant for that criterion, while other combinations were assigned value 0 (**Annex 1**). The values were assigned by the marine ecologists of the PBS GI activity group (representatives from Estonia, HELCOM, Latvia, Finland and Sweden). The assessment results were discussed during the 3rd GI workshop, held in Riga,12-13 December 2018, as well as commented by Finnish HELCOM experts[32].

Hierarchical data aggregation method was used to obtain maps representing core areas of ecological value. The calculations were made in an extension to the Baltic Sea Impact Index (BSII) calculation tool developed in the Pan Baltic Scope. The calculation steps for data aggregation included the following:

1. **Producing separate maps for each ecological value criterion in relation to each ecosystem component group** - benthic habitats, birds, fish and mammals (Table 2, Column 1). This potentially creates up to 24 maps (6 criteria x 4 ecosystem component groups). The selection is based on the matrix for the assessment of ecological value (Annex 1): for each criterion and ecosystem component group, all the ecosystem component layers which have been assigned a value of 1 for the given criterion are included. The distribution of ecological values in each map was obtained by summing up the selected ecosystem component layers for the ecological value criterion. The values in the resulting maps were normalised to range 0-1 in order to avoid over-domination of groups represented by a higher number of ecosystem data layers when the differences are further compared or aggregated;

2. **Producing aggregated ecological value maps for each ecosystem component group**. This potentially creates up to 4 maps, one for each group - benthic habitats, birds, fish and mammals. All separate maps from step 1 which represent the same ecosystem component group (Column 1 in table 2) were summed up. The values in the resulting maps were normalised to range 0-1;

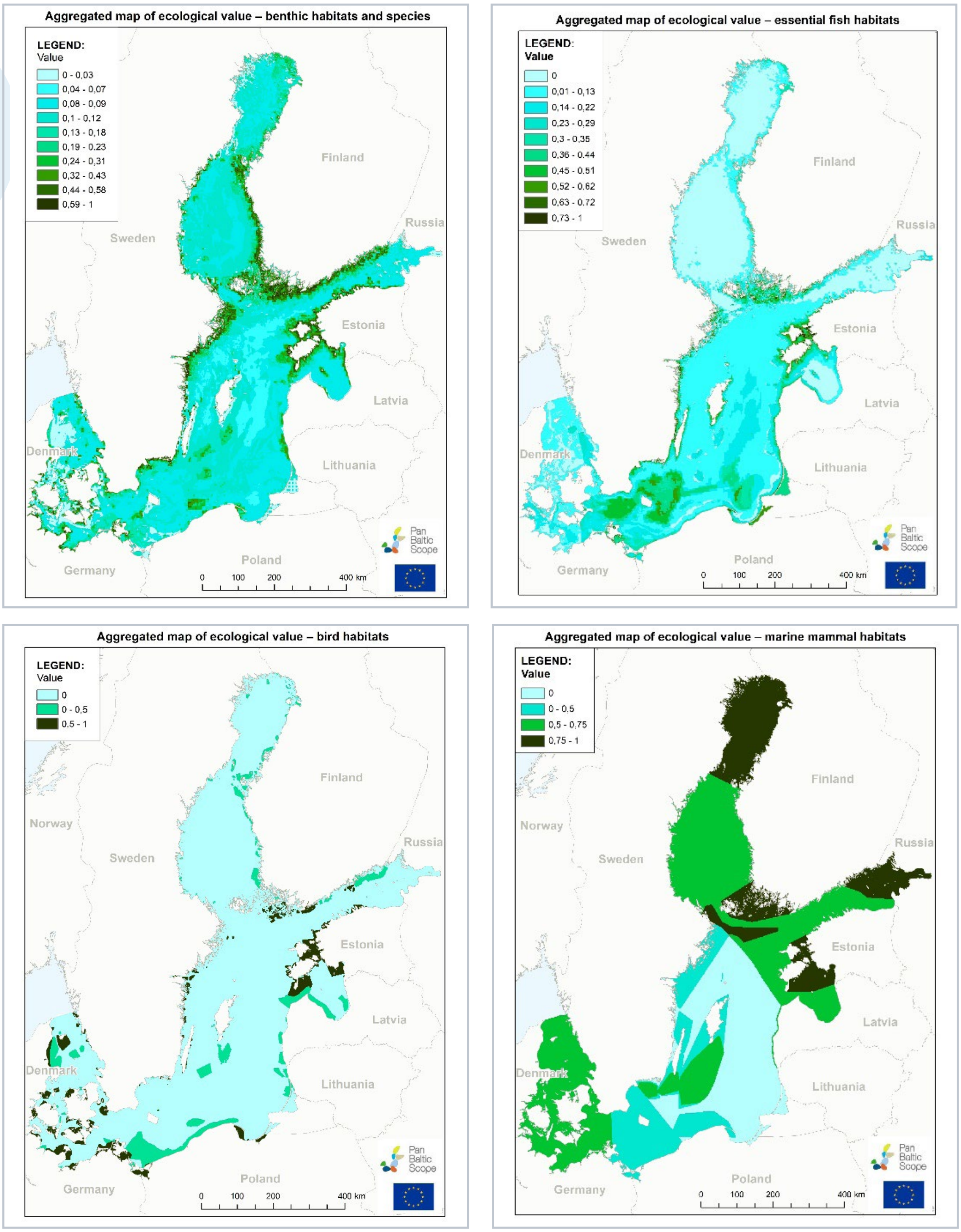
3. **Producing a total aggregated ecological value map:** All the aggregated ecological value maps from step 2 are merged by averaging. The values in the resulting map were normalised to range 0-1.

3.2.3. Results of mapping of ecological value

By using the approach described above (Step 1), initially 24 ecological value maps representing each criterion and ecosystem component group (benthic habitats & species, birds, fish, mammals) were obtained (Annex 3). The aggregated maps (Step 2) which combine the ecological values of the four ecological component groups are presented in Figure 13.

32 Finnish experts of the HELCOM State & Conservation group have suggested to expand the scoring to 0-2 (instead 0/1) as well as provided recommendations on each criterion how it could be ranked in relation to the different components (Annex 1.1). Such approach could be applied in further development of the method for mapping of the GI; however, it was not possible to modify the assessment matrix and consequently the maps on ecological values within the Pan Baltic Scope project, due to the set timeframe of the project activities and availability of experts.

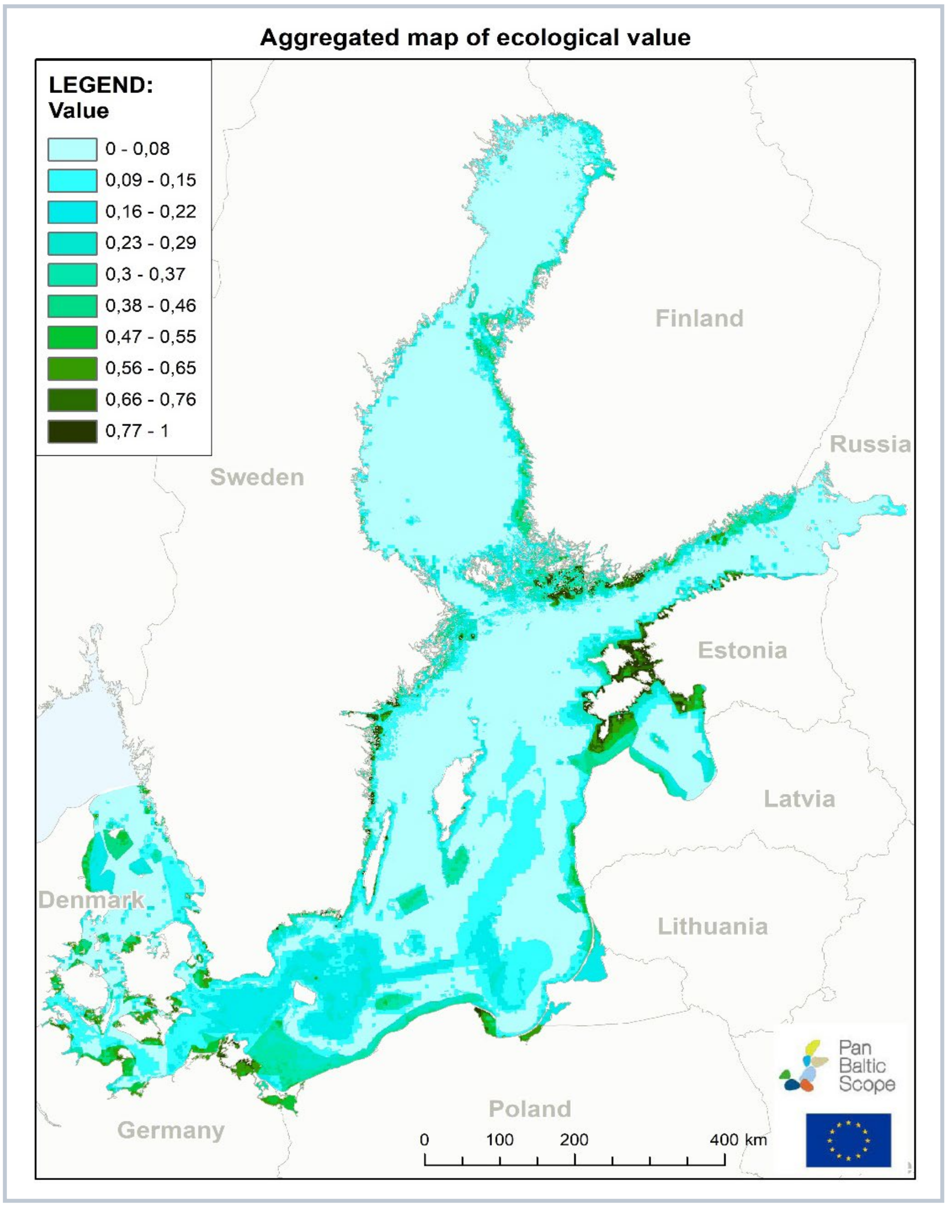
Fig. 13. Results of aggregated ecological value maps on four groups of ecosystem components: habitats, birds, fish, mammals.



By analysing the obtained mapping results, it became evident that the maps representing areas of ecological value to mammals were not sufficiently accurate. In order to be able to include the mammal data in the ecological value assessment, the ecosystem components data sets would need to be improved by more accurate data sets on distribution of the seal species or mammal habitats. 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. Since such data are not available at the Baltic Sea scale, the component of mammals has been temporarily removed from further data aggregation exercise.

Consequently, in the overall aggregated ecological value map (Step 3), the aggregated maps of only three ecosystem component groups, namely benthic habitats, fish and birds, were merged (Figure 14). Though, the mapping results reveal that the value of the bird habitats is slightly exaggerated within the aggregated ecological value map due to insufficient accuracy of the bird data.

Fig. 14. Map indicating the areas of high ecological value. The darker green colours represent areas of the highest value.



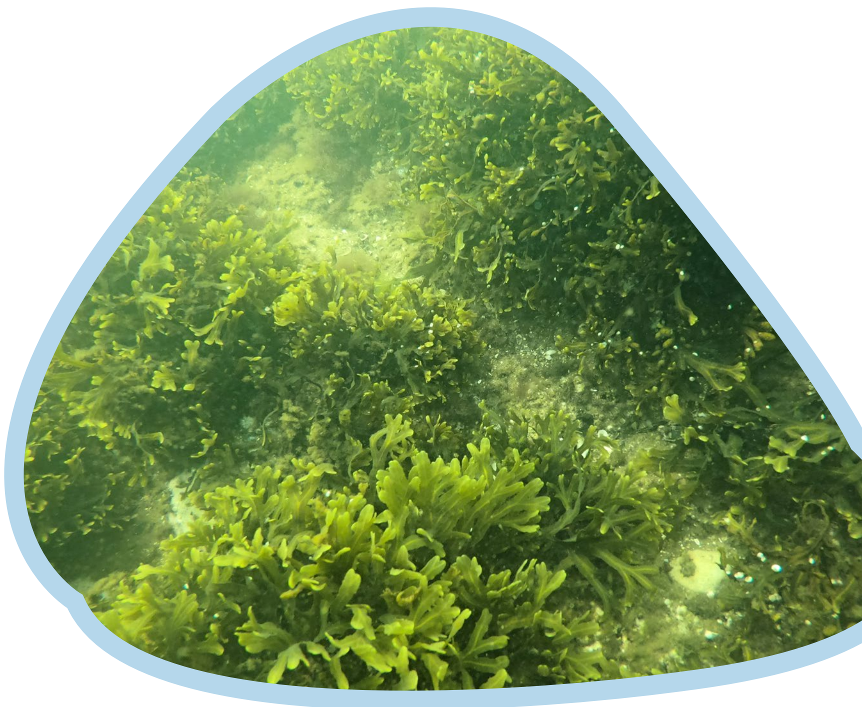
3.3. Mapping ecosystem service supply potential

3.3.1. Identification of ecosystem services essential for marine GI

As described above, ecosystem services demonstrate a link between ecosystem structures, processes and functions and derived economic and social benefits. Therefore, an assessment of ecosystem service supply is a crucial step in mapping GI.

In developing the Pan Baltic Scope proposal on ecosystem service assessment we have relied on expert knowledge and scientific publications on marine ecosystem services. In recent years marine ecosystem services have become a significant research topic. Several authors have proposed a typology and indicators for assessing marine ecosystem services [33] [34] [35]. A conceptual framework for mapping and assessing marine ecosystems and their services has been developed by a group of consultants within a background document for "Roadmap for an integrated approach to a marine MAES" [36].

The working group to support mapping and assessment of ecosystems and their services (MAES) at EU level, set up by the European Commission, has introduced the analytical framework for the assessment of ecosystem and their services under Target 2/Action 5 of the EU Biodiversity Strategy 2020[37]. The document describes the MAES ecosystem typology (including marine ecosystems) and suggests the Common International Classification of Ecosystem Services (CICES) to be used in the MAES process. In the Pan Baltic Scope, we have applied the CICES Version 5.1 (published in 2018) for mapping potential supply of ecosystem services. All the ecosystem services based on CICES, V5.1, which potentially could be relevant for the assessment of marine GI, are presented in Table 4.



33 Böhnke-Henrichs et al., 2013. Typology and indicators of ecosystem services for marine spatial planning and management. Journal of Environmental Management 130:135–145.

34 Liquete et al., 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PLoS ONE 8: e67737.

35 Hattam et al., 2015. Marine ecosystem services: Linking indicators to their classification. Ecological Indicators 4 :61–75.

36 Boon et al. 2015. Mapping and assessment of marine ecosystem services and link to Good Environmental Status (phase 1) - Background document to the Roadmap for an integrated approach to a marine MAES.

37 Maes et al. 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Publications office of the European Union, Luxembourg.: 60 pp.

Table 4. The ecosystem services (according to CICES V5.1) potentially relevant for mapping marine GI (services marked in green have been assessed by the Pan Baltic Scope project).

DIVISION	GROUP	CLASS (INCLUDING THE CICES V5.1 CODE)	SUB-CATEGORIES OF ECOSYSTEM SERVICES*
PROVISIONING SERVICES			
Biomass	Wild plants (terrestrial and aquatic) for nutrition, materials or energy	1.1.5.1. Wild plants (terrestrial and aquatic, including fungi, algae) used for nutrition	
		1.1.5.2. Fibres and other materials from wild plants for direct use or processing (excluding genetic materials)	
		1.1.5.3. Wild plants (terrestrial and aquatic, including fungi, algae) used as a source of energy	
	Wild animals for nutrition, materials or energy	1.1.6.1. Wild animals (terrestrial and aquatic) used for nutritional purposes (e.g. fish, mussels)	
REGULATION & MAINTENANCE SERVICES			
Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	2.1.1.1. Bioremediation by micro-organisms, algae, plants, and animals	
		2.1.1.2. Filtration/sequestration/storage/ accumulation by micro-organisms, algae, plants, and animals	Filtration of nutrients Storage of nutrients Storage of hazardous substances
Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	2.2.1.1. Control of erosion rates	
		2.2.1.2. Buffering and attenuation of mass movement	
		2.2.1.3. Hydrological cycle and water flow regulation (Including flood control, and coastal protection)	
Regulation of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	2.2.2.1. Pollination (or 'gamete' dispersal in a marine context)	
		2.2.2.2. Seed dispersal	
		2.2.2.3. Maintaining nursery populations and habitats (Including gene pool protection)	
Regulation of physical, chemical, biological conditions	Pest and disease control	2.2.3.1. Pest control (including invasive species)	
		2.2.3.2. Disease control	
Regulation of physical, chemical, biological conditions	Water conditions	2.2.5.2. Regulation of the chemical condition of salt waters by living processes	
Regulation of physical, chemical, biological conditions	Atmospheric composition and conditions	2.2.6.1. Regulation of chemical composition of atmosphere and oceans	Regulation of atmospheric CO_2 and other grenhouse gases by biological fixation in the process of photosynthesis Regulation of atmospheric CO_2 and other greenhouse gases by sequestration in sediments
		2.2.6.2. Regulation of temperature and humidity, including ventilation and transpiration	
CULTURAL SERVICES			
Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	3.1.1.1. Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions	
		3.1.1.2. Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions	
	Intellectual and representative interactions with natural environment	3.1.2.1. Characteristics of living systems that enable scientific investigation or creation of traditional ecological knowledge	
		3.1.2.2. Characteristics of living systems that enable education and training	

* sub-categories are proposed based on the marine ecosystem service classification applied in the BONUS BASMATI project.

The selection of the ecosystem services to be mapped were discussed during the Green Infra & Essential Fish Habitat workshops, held in Gothenburg, Sweden, 10-11 September 2018, as well as in Riga, 12-13 December 2018. The participants of the meeting agreed **to focus on regulation and maintenance services as well as cultural services** (related to recreation) since they link better to the concept of GI and could be feasible to mapping based on the available HELCOM data sets. Furthermore, we specified two CICES ecosystem service classes, providing sub-categories based on ecosystem service assessment work within the BONUS BASMATI project. The selected ecosystem service classes and sub-categories are listed below:

Regulation & Maintenance services

- Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals
  - Filtration of nutrients
  - Storage of nutrients
  - Storage of hazardous substances
- Control of erosion rates;
- Maintaining nursery populations and habitats (Including gene pool protection)
- Pest control (including invasive species)
- Regulation of chemical composition of the atmosphere and oceans
  - Regulation of atmospheric CO_2 and other greenhouse gases by biological fixation in the process of photosynthesis *(short name: Climate control by photosynthesis)*
  - Regulation of atmospheric CO_2 and other greenhouse gases by sequestration in sediments *(short name: Climate control by sequestration in sediments)*

Cultural services:

- Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through active or immersive interactions *(short name: Recreation through active interactions)*
- Characteristics of living systems that enable activities promoting health, recuperation or enjoyment through passive or observational interactions *(short name: Recreation through passive interactions).*

In addition to these, it could be argued that areas significant for some provisioning services (e.g. *Wild plants (e.g. algae) for nutrition, materials or energy* and *Wild animals (e.g. fish) for nutrition*) could be essential components of GI. In the work of the Pan Baltic Scope, we did not include provisioning services related to areas important for fish catch, since we consider the regulating and maintenance service *Maintaining nursery populations and habitats*, which can be mapped on the basis of fish spawning areas, to be more relevant in the functional context of GI, as it indicates areas important for the production of fish resources. Assessing areas which provide macroalgae resources might be controversial, since most potentially suitable areas are included in MPAs, where extraction of this resource is not allowed. The focus on regulation and maintenance services as most suitable for GI mapping also corresponds to the approach followed within the described pan-European case study (Liquete et al., 2015).

3.3.2. Methodology for mapping ecosystem service supply potential of marine areas

For mapping the ecosystem service supply, a second matrix was developed. The potential contribution of each ecosystem component to each of the selected ecosystem services (listed above and marked green in Table 3) was assigned, so that a 0 represented no or negligible contribution, while 1 was used when the ecosystem component was considered to contribute to the service. The resulting matrix is presented in Annex II. The assessment scores were obtained through an iterative process. At first, individual scoring was provided by the experts from Estonia, HELCOM, Latvia, Sweden, Finland and Germany, then the assessment results were compared. Any inconsistencies in the replies were discussed during two Skype meetings until a consensus on the assessment was reached.

A similar ecosystem services matrix approach based on expert knowledge and scientific literature has previously been successfully applied in several marine ecosystem service studies in situations when basic data on the distribution of marine habitats/ecosystem components are available[38]. The scoring in other matrix-based studies mostly involves a semi-quantitative scale. For example, scale 0-3 was applied in similar studies from the UK[39] and New Zealand[40], while HELCOM [41] used scale 0-4 for assessing the ecosystem service supply potential of marine ecosystem components. Nevertheless, the Pan Baltic Scope GI expert group decided to apply the simpler binary approach to recognise the currently limited knowledge and data on ecosystem service supply under the Baltic Sea conditions. A more elaborate version of the matrix approach to the ecosystem service assessment could be considered in the future. For example, Culhange et al.[42] developed a network model to demonstrate the complex sets of interactions between different taxa and their habitats (as service providing units), and the ecosystem service supply.

The matrix (Annex II) was used as a basis for developing maps on ecosystem services, with a similar hierarchical data aggregation method as in the case of ecological value mapping. Though in this case mapping included the ecosystem component groups representing benthic habitats (including essential fish habitats) and bird habitats. The data sets on mammal distribution were excluded from the development of the aggregated ecosystem service maps due to the reasons described above (Chapter 3.2.3.).

In order to avoid domination of results that were represented by many data layers as well as double counting of the ecosystem service supply value (in fact some similar ecosystem component layers may represent the same features providing ecosystem services), a slightly different hierarchical data aggregation approach was applied. The calculation steps for data aggregation included the following:

1. **Producing separate maps for each ecosystem service provided by each ecosystem component sub-group** (Table 2, Column 2: marine landscapes, Natura 2000 habitats, key benthic species, essential fish habitats and bird habitats). This potentially creates a high number of maps (N ecosystem services x N ecosystem component sub-groups). However, all theoretically possible combinations were not used. The selection was based on the matrix for assessment of ecosystem services (Annex 2): the value in each grid cell of the resulting raster represented the sum for all

38 Townsend et al., 2018. The Challenge of Implementing the Marine Ecosystem Service Concept. Frontiers in Marine Science. Vol. 5, Article 359.

39 Potts et al., 2014. Do marine protected areas deliver flows of ecosystem services to support human welfare? Marine Policy, 44: 139–148.

40 Geange et al., 2019. Communicating the value of marine conservation using an ecosystem service matrix approach. Ecosystem Services, 35: 150–163.

41 Ahtiainen et al. Developing the ecosystem service approach in the ESA framework, SPICE project deliverable: WT 3.1.3, HELCOM.

42 Culhane et al., 2018. Linking marine ecosystems with the services they supply: what are the relevant service providing units? Ecological Applications, 28: 1740-1751.

ecosystem components of the sub-group which had been assigned value 1 for the concerned ecosystem service. The values in the resulting maps were normalised to range 0-1;

2. **Producing aggregated ecological value maps for the ecosystem component groups.** First, the single ecosystem service values were summed up in the five sub-groups of the ecosystem components and the results were normalised to range 0-1. Then, the results of the assessments in the sub-groups were combined on the level of the ecosystem component groups (Table 2, Column 2). The sub-groups of marine landscapes, Natura 2000 habitats, key benthic species and essential fish habitats were merged in the group "Benthic habitats", while the "Birds" were used directly as the group "Bird habitats". The data were merged so that the highest value from any of these sub-group maps is retained in each cell. The values in the resulting maps were normalised to range 0-1.
3. **Producing a total aggregated ecosystem service map** by adding the values from the aggregated maps on benthic habitat and birds. The values in resulting map were normalised to range 0-1.

Additionally, a table on all GI related ecosystem services was prepared on the basis of CICES V5.1., providing an explanation for each ecosystem service as well as potential indicators, proposed by Hattam et al. (2015) and other studies (including HELCOM core indicators), which could be applied for quantitative assessment of ES supply (see Annex 4). Selected indicators were used to focus the expert assessment when filling in the matrix.

3.3.3. Results of mapping ecosystem service supply potential

Following the approach described in Step 1, in total 37 single ecosystem service maps were obtained, which illustrate 10 ecosystem services provided by five ecosystem component sub-groups (Annex 4). 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 15. The aggregated ecosystem services map, which sums up the values of the aggregated benthic habitat and fish maps, is presented in Figure 16.

Fig. 15. Aggregated ecosystem service maps of the two ecosystem component groups: all benthic habitats, and species and birds' habitats.

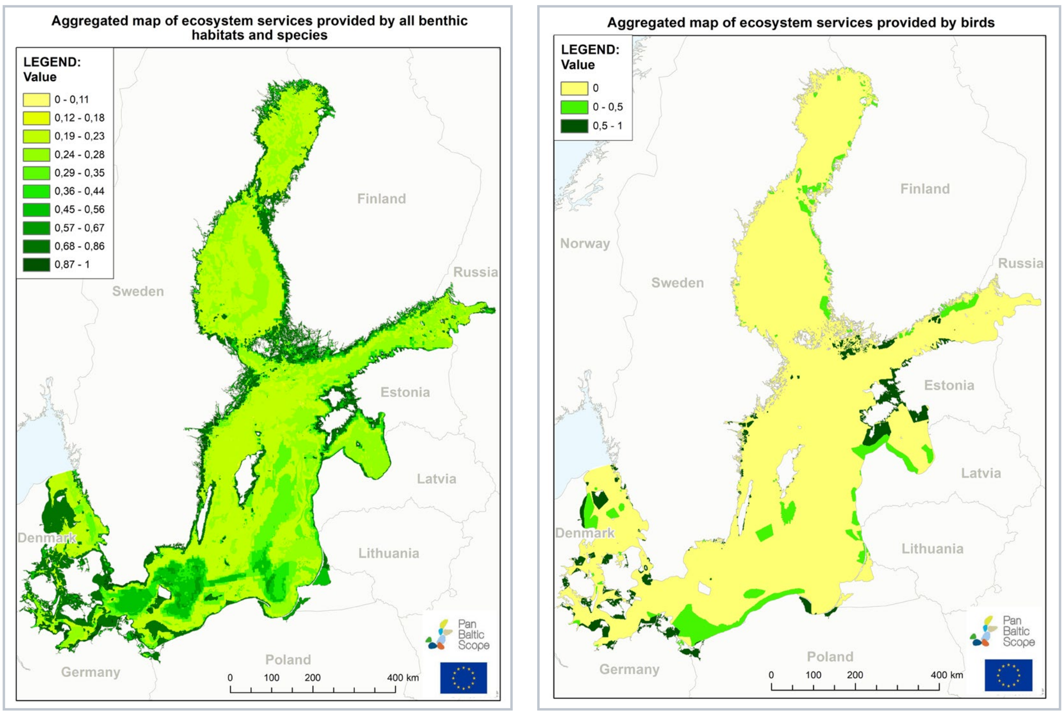
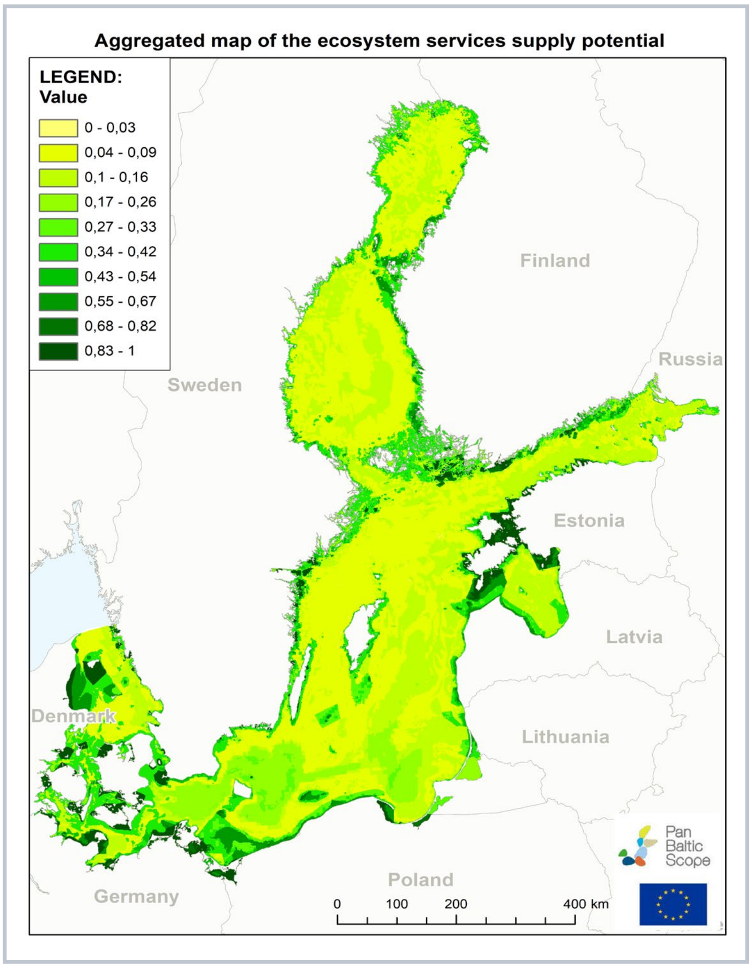


Fig. 16. Aggregated map of the ecosystem service supply potential

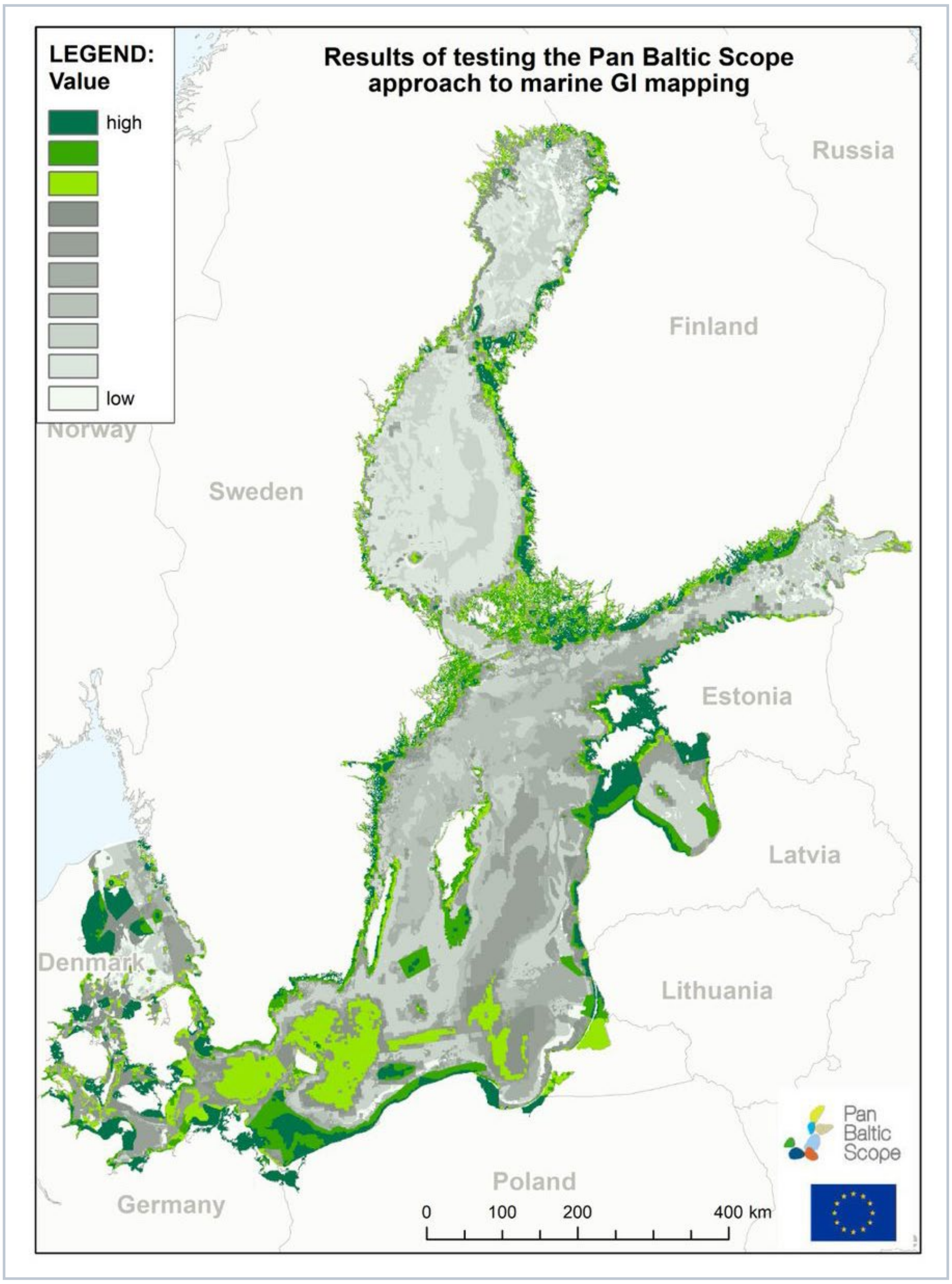


The aggregated map indicates the multi-functionality of the areas in relation to ecosystem service supply, where higher value is shown for areas that have a potential to deliver more ecosystem services. However, same as in the case of the ecological value mapping, the value of the bird habitats is slightly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

3.4. Development of GI map

In order to identify the areas potentially forming marine GI, the results from mapping the ecological value (Figure 14) and potential for ecosystem service supply (Figure 16) were aggregated. Following the method for GI mapping at the EU scale proposed by Liquete et al. (2015), the core GI areas should include the areas which have the highest ecological value and/or highest value for ecosystem service supply. This approach is in line with the EC definition of GI, which encompasses a network of natural and semi-natural areas managed for protection of biodiversity and delivery of wide range of ecosystem services. However, setting a threshold above which the area would be considered of a high value is rather an arbitrary decision taken by experts or decision makers. Here we offer an option that the 30 % of the Baltic Sea area with the highest scores for aggregated ecological and ecosystem service supply value to be recognised as marine GI (Figure 17).

Fig.17 Results of the 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).



The Pan Baltic Scope GI mapping approach was tested also at national scale within Latvian case study (**annex 5**). The analysis includes less ecosystem components, but more accurate data sets available for the Latvian marine waters. The case study demonstrates the possibilities for adjusting the proposed methodology for more detailed national or local scale analysis.

Another option, discussed in the GI expert group, would be to perform multivariate analysis of all ecosystem components in relation to the selected criteria for high ecological value and ecosystem services supply. Such a GI map could illustrate the functional heterogeneity of marine areas. However, performing such an analysis was not feasible within the scope of the Pan Baltic Scope project due to limited time and human resource capacities.

4. Conclusions on possibilities for mapping marine GI and its application in MSP

The Pan Baltic Scope project interprets the 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.**

The presented approach to GI mapping follows the definition proposed by the EC Communication on Green Infrastructure[43] and the methodology for mapping GI at EU scale suggested by the European Environmental Agency[44]. The Pan Baltic Scope project has tested GI mapping at the scale of the Baltic Sea, covering the two essential aspects, i.e. identification of areas of high ecological value and potential supply of ecosystem services. The data set of the HELCOM HOLAS II Ecosystem Components (the only harmonised data set for the entire Baltic Sea) was used as the basis for the GI mapping. The proposed approach can also be applied at national/regional scale using other available (more precise) spatial data on the distribution of marine ecosystem components.

The presented approach has certain limitations, which should be addressed in future studies:

- Knowledge and data gaps limit the content and quality of the current result maps.
- 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.
- The present approach to ecosystem services mapping provides only indicative assessment of potential service supply. The actual ecosystem service supply is defined by i) spatial variations in biota, ecosystem functioning and hence service provision; ii) ecosystem condition and vulnerability of ecosystem services to cumulative pressures; iii) ecosystem service supply and demand relation.

Nevertheless, the GI mapping can support marine planning authorities by providing an essential input for the application of an ecosystem-based approach in MSP and increase relational understanding on the functioning of the marine ecosystem and its contribution to societal benefits. It includes the following aspects:

- GI concept helps to develop the knowledge base on marine ecosystem structure, functioning and service supply;
- GI mapping results can be considered in development of spatial planning solutions to guide away potentially harmful development from ecologically valuable/sensitive areas (contributes to precautionary principle);

43 COM(2013)249. In http://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF

44 Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B., et al. (2015). Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. Environmental Science and Policy, 54, 268–280.

- GI mapping can be used to support cross-border coordination of planning solutions in respect to ecological values;
- GI mapping results can be used in SEA procedure of the MSPs and other development plans to assess impacts on the marine ecosystem and potential for delivery of wide range of ecosystem services;
- The obtained information can improve communication among different stakeholders about the sea use potentials and limitations at national as well as cross-national/basin-wide scale, etc.;
- Consideration of GI in MSP process helps to maintain the multi-functionality of the marine ecosystem by providing a wide range of ecosystem services.

Furthermore, GI mapping can support nature conservation authorities in improving the coherence of the existing MPA network. This includes the following aspects:

- GI mapping can be used to assess the connectivity of the MPA network (i.e. conditions for species distribution)
- GI mapping can help to identify areas of high ecological value which are not included in MPA network – this information can guide field investigations of potential MPAs

The Pan Baltic Scope GI concept can contribute towards a holistic perspective linking MSP to environmental management through GI. Both MSP and the development of marine protected areas 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 linking planning and management is needed, as well as common development of knowledge of the Baltic ecosystems.

References

Ahtiainen H., Holma M., Mentzer J., Nommann T., Oinonen S., Pakalniete K., Tuhkanen H., Vretborn M. Developing the ecosystem service approach in the ESA framework, SPICE project deliverable: WT 3.1.3, HELCOM .

Boon, A., Uyarra, M.C.,Heiskanen, A.S., van der Meulen, M.D., Galparsoro, I., Viitasalo, M., Mikel, J., Murillas, A., Borja, A., 2015. Mapping and assessment of marine ecosystem services and link to Good Environmental Status (phase 1) - Background document to the Roadmap for an integrated approach to a marine MAES. 10.13140/RG.2.2.28660.35204.

Böhnke-Henrichs, A., C. Baulcomb, R. Koss, S. S. Hussain, and R.S. de Groot. 2013. Typology and indicators of ecosystem services for marine spatial planning and management. Journal of Environmental Management 130:135–145.

Burkhard B., de Groot R., Costanza R., Seppelt R., Jørgensen S.E. & Potschin M. (2012). Solutions for sustaining natural capital and ecosystem services. Ecological Indicators, 21: 1 – 6.

Culhane F.E, Frid C.L.J., Gelabert E.R., White L., Robinson L.A., 2018. Linking marine ecosystems with the services they supply: what are the relevant service providing units? Ecological Applications, 28: 1740-1751.

Estreguil, C., Dige, G., Kleeschulte, S., Carrao, H., Raynal, J. and Teller, A., 2019. Strategic Green Infrastructure and Ecosystem Restoration: geospatial methods, data and tools, EUR 29449 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-97294-2, doi:10.2760/06072, JRC113815.

European Commission (2013). Green infrastructure (GI) – Enhancing Europe's Natural Capital. COM(2013)249. In http://eur-lex.europa.eu/resource.html?uri=cellar:d41348f2-01d5-4abe-b817-4c73e6f1b2df.0014.03/DOC_1&format=PDF

European Union, 2013. Building a Green Infrastructure for Europe. Available at: http://ec.europa.eu/environment/nature/ecosystems/docs/green_infrastructure_broc.pdf

Federal Agency for Nature Conservation (BfN) (2017). Federal Green Infrastructure Concept. https://www.bfn.de/fileadmin/BfN/planung/bkgi/Dokumente/BKGI_Broschuere_englisch.pdf

Forman, R.T. T. & Godron M. 1986. Landscape Ecology. John Wiley and Sons (New York)

Fulmer, J.E. (2009). What in the world is infrastructure? Infrastructure Investor 9, 30–32.

Geange S., Townsend M., Clark D., Ellis J.I., Lohrer A.M., 2019. Communicating the value of marine conservation using an ecosystem service matrix approach. Ecosystem Services, 35: 150–163.

Haines-Young, R., Potschin M., 2010. The links between biodiversity, ecosystem services and human well-being. In: Raffaelli, D.G & C.L.J. Frid (eds.): Ecosystem Ecology: A New Synthesis. Cambridge University Press, British Ecological Society, pp. 110-139.

Hattam C., Atkins J.P. , Beaumont N., Börger T., Böhnke-Henrichs A. , Burdon D. , de Groot R. , Hoefnagel E. , Nunes P. A.L.D. , Piwowarczyk J. , Sastre S , Austen M.C., 2015. Marine ecosystem services: Linking indicators to their classification. Ecological Indicators 4:61–75.

HELCOM-VASAB MSP working group (2017). Background document on "Green infrastructure"/ "Blue corridors". HELCOM Secretariat, Code: 4-3.

Jongman et al., 2011. The pan European ecological network: "PEEN". Landscape Ecology, 26: 311–326.

Kukkala A.S. & Moilanen A., 2017. Ecosystem services and connectivity in spatial conservation prioritization. Landscape Ecology, 32:5-14.

La Notte et al., 2017. Ecosystem services classification: A systems ecology perspective of the cascade framework. Ecological Indicators, 74:392–402.

Liquete, C., C. Piroddi, E. G. Drakou, L. Gurney, S. Katsanevakis, A. Charef, and B. Egoh. 2013. Current status and future prospects for the assessment of marine and coastal ecosystem services: a systematic review. PLoS ONE 8:e67737.

Liquete, C., Kleeschulte, S., Dige, G., Maes, J., Grizzetti, B., Olah, B., et al. (2015). Mapping green infrastructure based on ecosystem services and ecological networks: A Pan-European case study. Environmental Science and Policy, 54, 268–280.

Maes, J., A. Teller, M. Erhard, C. Liquete, L. Braat, P. Berry, B. Egoh, P. Puydarrieux, C. Fiorina, F. Santos, M. L. Paracchini, H. Keune, H. Wittmer, J. Hauck, I. Fiala, P. H. Verburg, S. Condé, J. P. Schägner, J. San Miguel, C. Estreguil, O. Ostermann, J. I. Barredo, H. M. Pereira, A. Stott, V. Laporte, A. Meiner, B. Olah, E. Royo Gelabert, R. Spyropoulou, J. E. Petersen, C. Maguire, N. Zal, E. Achilleos, A. Rubin, L. Ledoux, C. Brown, C. Raes, S. Jacobs, M. Vandewalle, D. Connor, G. Bidoglio, 2013. Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under Action 5 of the EU Biodiversity Strategy to 2020. Publications office of the European Union, Luxembourg.: 60 pp.

Mander et al., 2018. Green and brown infrastructures support a landscape-level implementation of ecological engineering. Ecological Engineering 120: 23–35.

Potschin-Young, M., Haines-Young, R., Görg, C., Heink, U., Jax, K., C. Schleyer, 2018. Understanding the role of Conceptual Frameworks: Reading the Ecosystem Service Cascade. Ecosystem Services, 29:428-440.

Potts T., Burdon D., Jackson E., Atkins J., Saunders J., Hastings E., Langmead O. (2014). Do marine protected areas deliver flows of ecosystem services to support human welfare? Marine Policy, 44: 139–148.

Rega C., 2019. Towards and Effective Implementation of Green Infrastructure in Rural Areas. Challenges and Options for a Substantial Integration with Spatial Planning. In: Gottero E. (Eds.). Agrourbanism. Tools for Governance and Planning of Agrarian Landscape. Springer Nature Switzerland AG., p. 73-85.

Rudnick D.A. Ryan S.J., Beier P., Cushman S.A., Dieffenbach F., Epps C.W., et al. 2012. The role of landscape connectivity in planning and implementing conservation and restoration priorities. Issues in Ecology, 16:1-23.

Sepp, K., Kaasik, A. (Eds.), 2002. Development of National Ecological Networks in the Baltic Countries in the Framework of Pan-European Ecological Network. IUCN European Programme, Warsaw, Poland. International Union for Conservation of Nature (IUCN), Gland, Switzerland. 183 pp.

da Silva J.M.C. & Wheeler E. (2017). Ecosystems as infrastructure. Perspectives in ecology and conservation. 15: 32-35

Townsend M., Davies K., Hanley N., Judi E. Hewitt J.E., Lundquist C.J., Lohrer A.M., 2018. The Challenge of Implementing the Marine Ecosystem Service Concept. Frontiers in Marine Science. Vol. 5, Article 359.

Vallecilloa S., Polce C., Barbosa A., Castillo C.P., Vandecasteele I., Rusch G.M., Maes J. (2018). Spatial alternatives for Green Infrastructure planning across the EU: An ecosystem service perspective. Landscape and Urban Planning, 174: 41-54.

Veidemane K., Ruskule A., Strake S., Purina I., Aigars J., Sprukta S., Ustups D., Putnis I. & Klepers A. (2017) Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia, International Journal of Biodiversity Science, Ecosystem Services & Management, 13:1, 398-411.

Annex 1: Matrix for assessment of ecological value of marine ecosystem components

HELCOM BSII Ecological Diversity Components	Biodiversity	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	Biological productivity
Availability of deep water habitat, based on occurrence of H2S	0	1	0	0	0	0
Infralittoral hard bottom	0	1	0	0	0	0
Infralittoral sand	0	1	0	0	0	0
Infralittoral mud	0	1	0	0	0	0
Infralittoral mixed	0	1	0	0	0	0
Circalittoral hard bottom	1	1	1	1	1	1
Circalittoral sand	0	1	1	1	1	1
Circalittoral mud	0	1	1	1	1	1
Circalittoral mixed	1	1	1	1	1	1
Sandbanks which are slightly covered by sea water at all time (1110)	1	1	1	1	1	1
Estuaries (1130)	1	1	1	0	1	1
Mudflats and sandflats not covered by seawater at low tide (1140)	0	1	0	0	0	0
Coastal lagoons (1150)	1	1	1	0	1	1
Large shallow inlets and bays (1160)	1	1	1	1	1	1
Reefs (1170)	1	1	1	1	1	1
Submarine structures made by leaking gas (1180)	1	1	1	1	1	1
Baltic Esker Islands (UW parts, 1610)	1	1	1	1	1	1
Boreal Baltic islets and small islands (UW parts, 1620)	1	1	1	1	1	1
Furcellaria lumbricalis	1	1	1	1	1	1
Zostera marina	1	1	1	1	1	1
Charophytes	1	1	1	1	1	1
Mytilus sp.	1	1	1	1	1	1
Fucus sp.	1	1	1	1	1	1
Productive surface waters	1	1	1	0	1	1
Cod abundance	0	0	1	0	0	1
Cod spawning area	1	1	1	1	1	1
Herring abundance	0	0	0	0	0	1
Sprat abundance	0	0	0	0	0	1
Recruitment areas of perch	1	1	1	1	1	1
Recruitment areas of pikeperch	0	1	1	1	1	1
Wintering seabirds	1	1	1	1	1	0
Breeding seabird colonies	1	1	1	1	1	0
Grey seal distribution	0	0	0	0	0	0
Harbour seal distribution	0	0	0	0	0	0
Ringed seal distribution	1	1	1	1	0	0
Distribution of harbour porpoise	1	1	1	1	0	0

Annex 1.1: Comments from Finland to the 5J-3: Outline of the Green Infrastructure concept for MSP and its application within Pan Baltic Scope project, Annex 1

We find that this kind of usage of EBSA-criteria is not well suited for scoring of ecosystem components. The EBSA-criteria have been developed in order to be able to delineate areas fulfilling the criteria. So, the original idea has been to apply these criteria in combination with different ecosystem components to delineate areas, not to classify or score the ecosystem components themselves.

If this kind of classification would still be used, we would suggest splitting the table into habitats and species, as the applicability of the criteria differs between these. Also, the binary ranking (0/1) of the current table could be further broadened to show differences among the habitats and species. Below are listed some suggestions and ideas on how to possibly further improve the scoring based on what is stated above, along with some further observations concerning the current ranking.

The criteria were modified to better reflect the focus of this scoring. Only the Rarity criterion is applicable to species, but the following species layers can be considered as habitats: recruitment areas, bird colonies.

Biodiversity: Applicable only to habitats and habitat-forming species. One should separate between broad habitats and more specific habitats. For example, if scoring is done between 0 and 2, score 0-1 could be given to broad habitats and some Natura 2000 habitats and score 1 and 2 denote richer communities and could be given to other habitats.

Rarity: Rarity indicates that a species or habitat does not occur commonly in all areas. One could score it (e.g. 0-2) depending on in how many HELCOM sub-basins the feature is found in. For example, score them 2 if it occurs in one sub-basin only, 1 if it is found from a couple of sub-basins and 0 if it is more common. In addition, one could have another set of criteria to define rarity.

More generally the concept of rarity doesn´t seem to fit on the broad scale habitat types, which by definition are common.

Importance for threatened, endangered or declining species and/or habitats: Applicable to habitats only. This seems to be partly overlapping with the 'biodiversity' criterion. Should be defined more clearly how it differs from that (e.g. can one separate which habitats really support red-listed species/habitats). Scoring could be 0 or 1.

Special importance for life-history stages of species: Applicable to habitats only. This requires careful definition because all the habitats are used by some species. What is 'special importance'? Do we know from the Baltic those habitats which are used key species? Scoring could be 0 or 1.

Biological productivity: This criterion seem a bit ill fitted for the Baltic Sea. The criterion has been developed to fit more oceanic environments which are generally nutrient poor. In these environments areas of high biological productivity are very important, but in a Baltic concept this might lean towards eutrophication, which is generally seen as an unwelcomed aspect. Some aspects of this, e.g. providing spawning grounds for fish or being able to sustain high biodiversity, would fit better under "Importance for threatened, endangered or declining species and/or habitats" and "Biodiversity" respectively.

Annex 2: Matrix for assessment of marine GI related ecosystem services

Scores: 0 – ecosystem component has no or negligible contribution to particular service; 1 – ecosystem component can provide the service

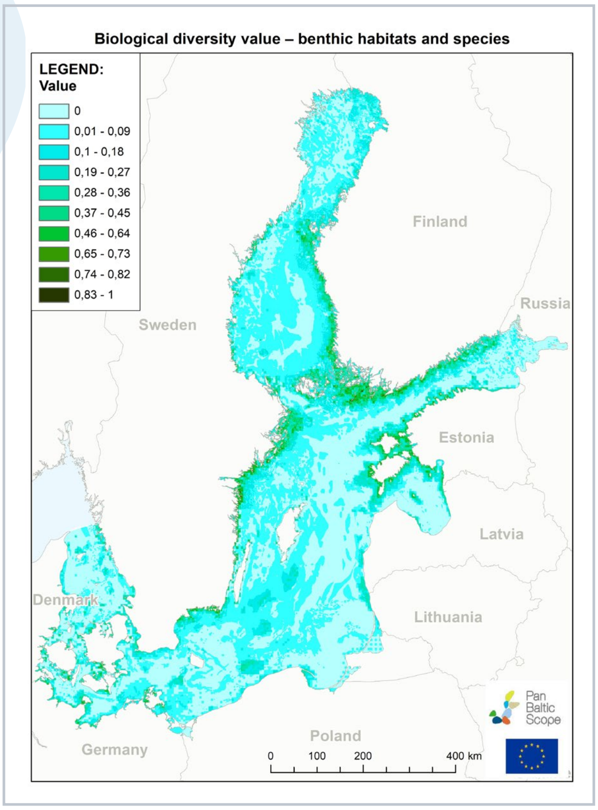
HELCOM BSII Ecological Diversity Components	Filtration/sequestration/ storage/accumulation by micro-organisms, algae, plants, and animals			Control of erosion rates	Maintaining nursery populations and habitats	Pest control (including invasive species)	Regulation of chemical composition of atmosphere and oceans (atmospheric CO^2 and other greenhouse gases):		Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment	
	filtration of nutrients	storage of nutrients	storage of hazardous substances				by biological fixation in process of photosynthesis	by sequestration in sediments	through active or immersive interactions	through passive or observational interactions
Availability of deep water habitat, based on occurrence of H2S	0	1	1	0	0	0	0	1	0	0
Infralittoral hard bottom	1	1	1	1	1	0	1	0	1	1
Infralittoral sand	0	1	1	0	1	0	1	0	1	1
Infralittoral mud	0	1	1	0	1	0	1	1	0	0
Infralittoral mixed	1	1	1	1	1	0	1	0	0	0
Circalittoral hard bottom	1	1	1	0	0	0	0	0	0	0
Circalittoral sand	0	1	1	0	0	0	0	0	0	0
Circalittoral mud	0	1	1	0	0	0	0	1	0	0
Circalittoral mixed	0	1	1	0	0	0	0	0	0	0
Sandbanks which are slightly covered by sea water at all time (1110)	0	1	1	0	1	0	1	0	1	1
Estuaries (1130)	1	1	1	0	1	0	1	1	1	1
Mudflats and sandflats not covered by seawater at low tide (1140)	0	1	1	0	1	0	1	1	1	1
Coastal lagoons (1150)	1	1	1	0	1	0	1	1	1	1
Large shallow inlets and bays (1160)	1	1	1	0	1	0	1	1	1	1
Reefs (1170)	1	1	1	1	1	0	1	0	1	1
Submarine structures made by leaking gas (1180)	0	1	1	0	0	0	0	0	0	0
Baltic Esker Islands (UW parts, 1610)	1	1	1	1	1	0	1	1	1	1
Boreal Baltic islets and small islands (UW parts, 1620)	1	1	1	1	1	0	1	1	1	1
Furcellaria lumbricalis	0	1	1	0	1	0	1	0	1	1
Zostera marina	0	1	1	1	1	0	1	1	1	1

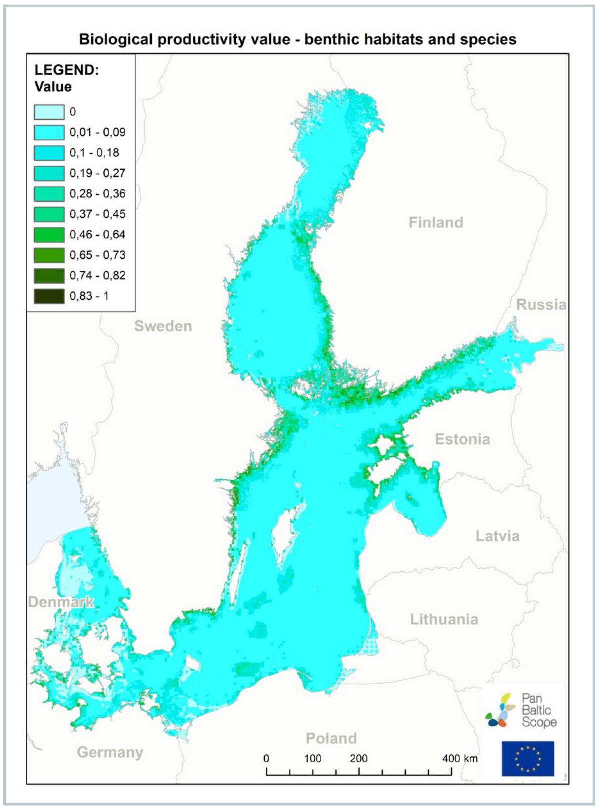
Charophytes	0	1	1	0	1	0	1	1	1	1
Mytilus sp.	1	1	1	0	1	0	0	0	1	1
Fucus sp.	0	1	1	0	1	0	1	0	1	1
Productive surface waters	1	0	0	0	1	0	1	0	1	1
Cod abundance	0	1	1	0	0	1	0	0	1	0
Cod spawning area	0	1	1	0	1	1	0	0	0	0
Herring abundance	0	1	1	0	0	0	0	0	1	0
Sprat abundance	0	1	1	0	0	0	0	0	1	0
Recruitment areas of perch	0	1	1	0	1	1	0	0	0	0
Recruitment areas of pikeperch	0	1	1	0	1	1	0	0	0	0
Wintering seabirds	0	1	1	0	0	1	0	0	1	1
Breeding seabird colonies	0	1	1	0	0	1	0	0	1	1
Grey seal distribution	0	1	0	0	0	0	0	0	1	1
Harbour seal distribution	0	1	0	0	0	0	0	0	1	1
Ringed seal distribution	0	1	0	0	0	0	0	0	1	1
Distribution of harbour porpoise	0	0	0	0	0	0	0	0	1	1

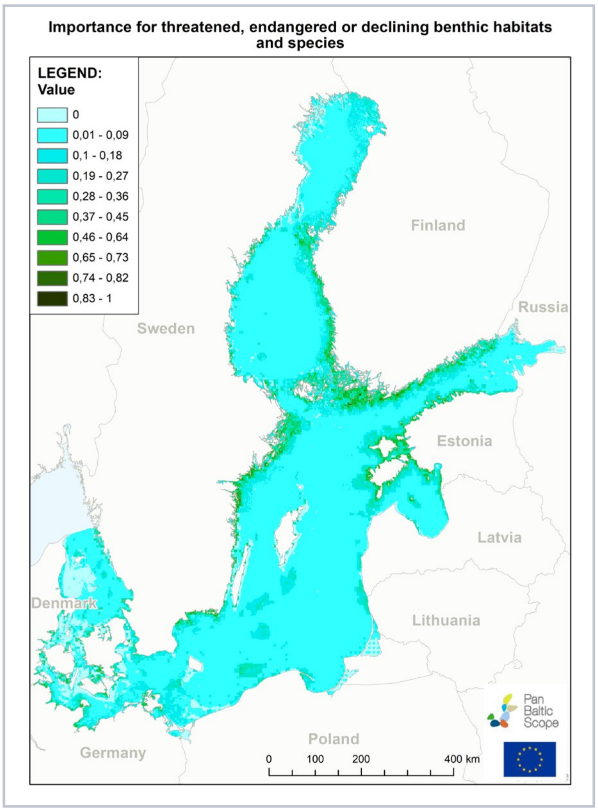
Confidence: yellow cells – assessment based on scientific literature/results from other studies; while cells – expert opinion

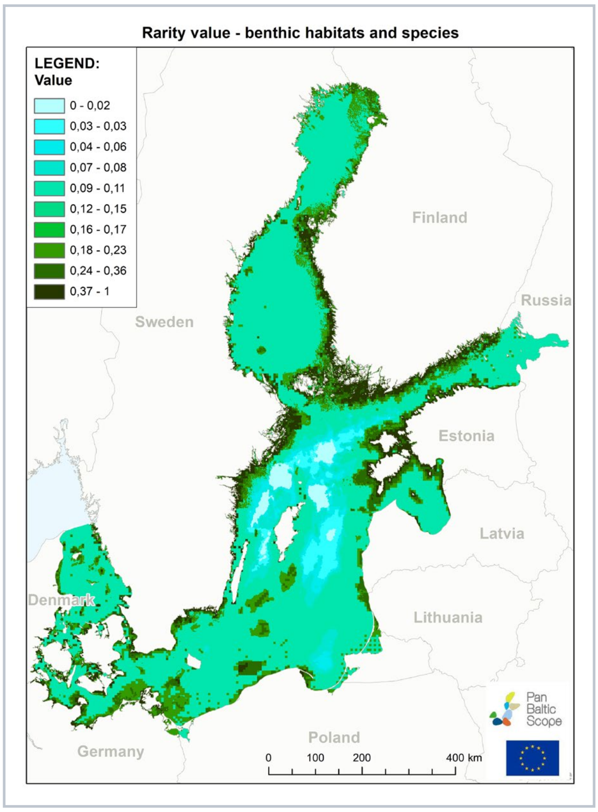
Annex 3: Ecological value maps for each criterion

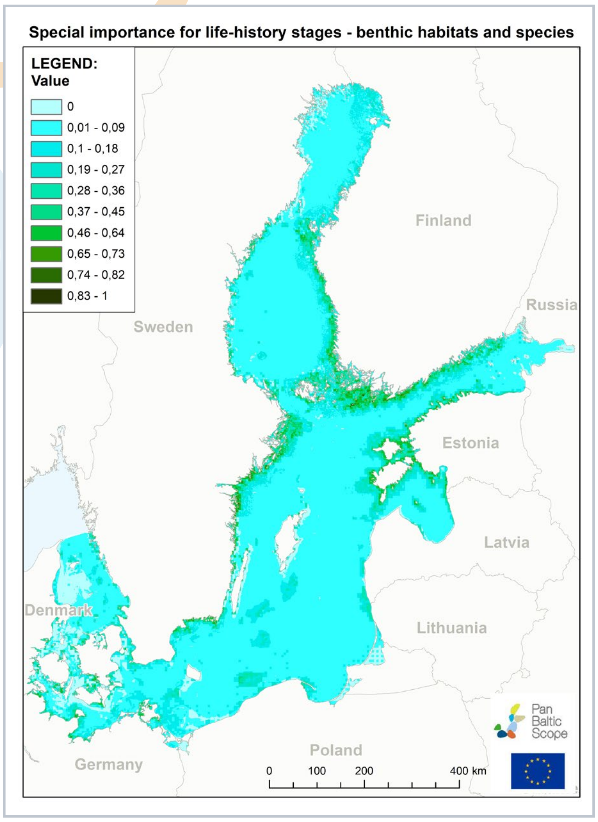
3.1. Ecological value – benthic habitats and species

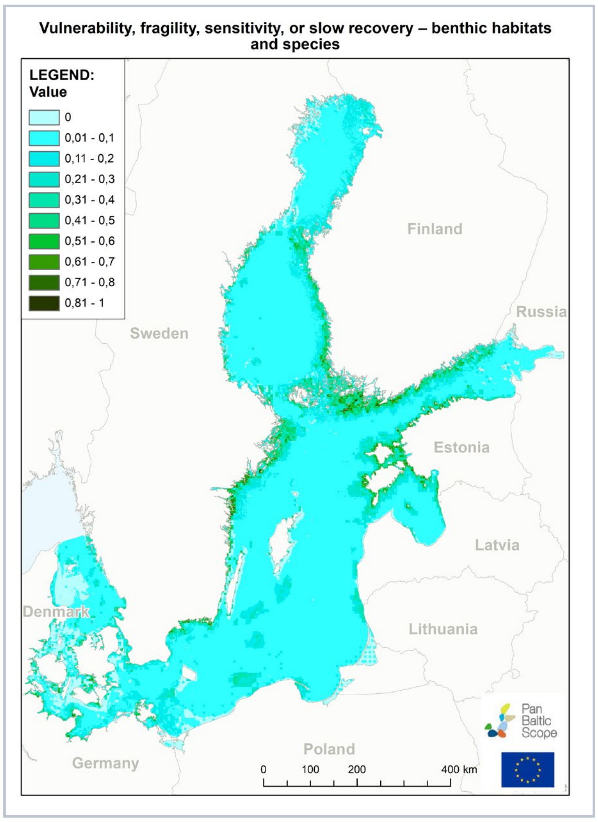




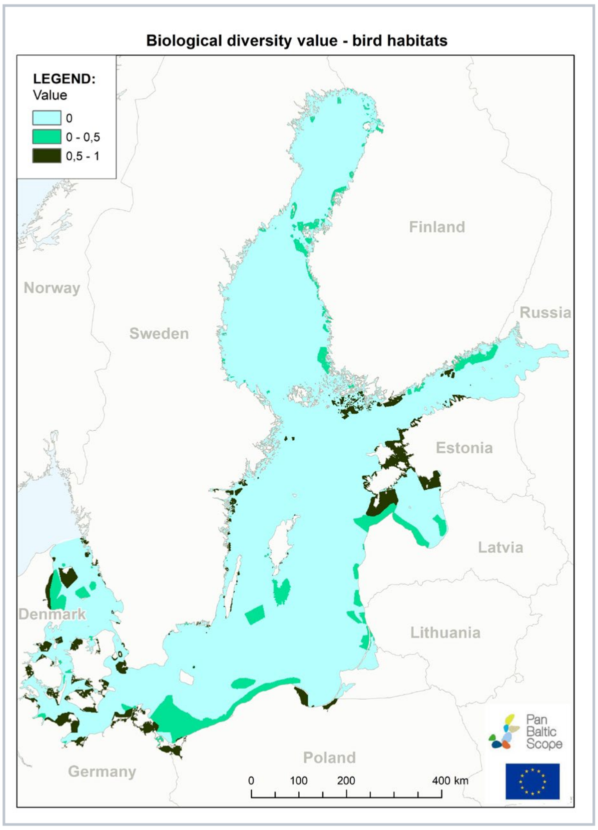


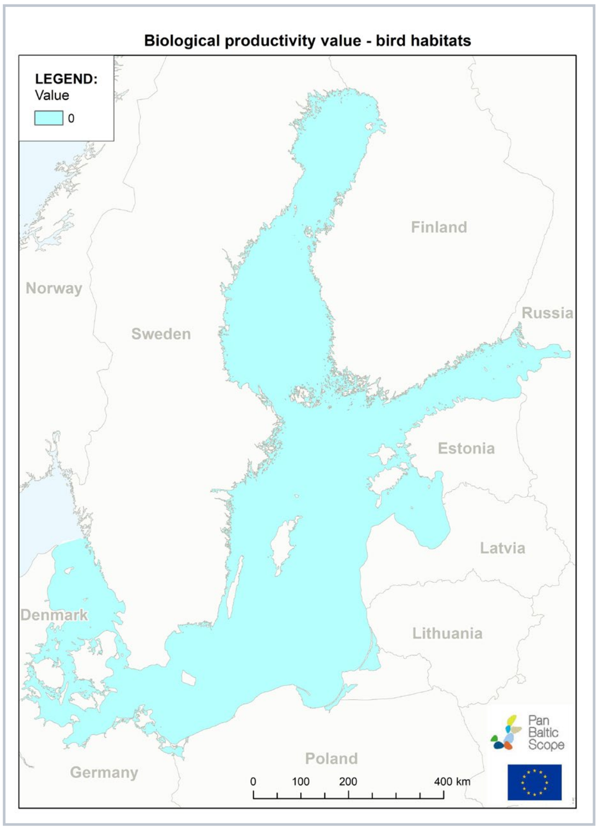


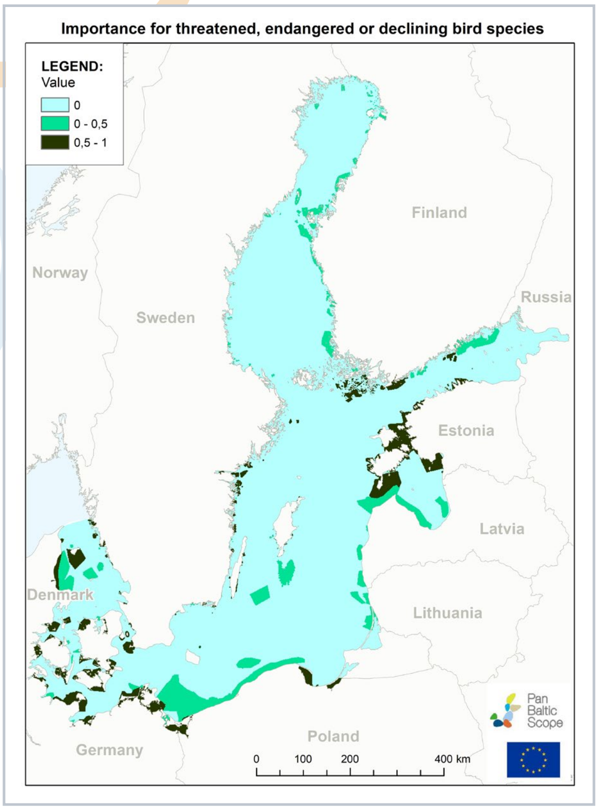


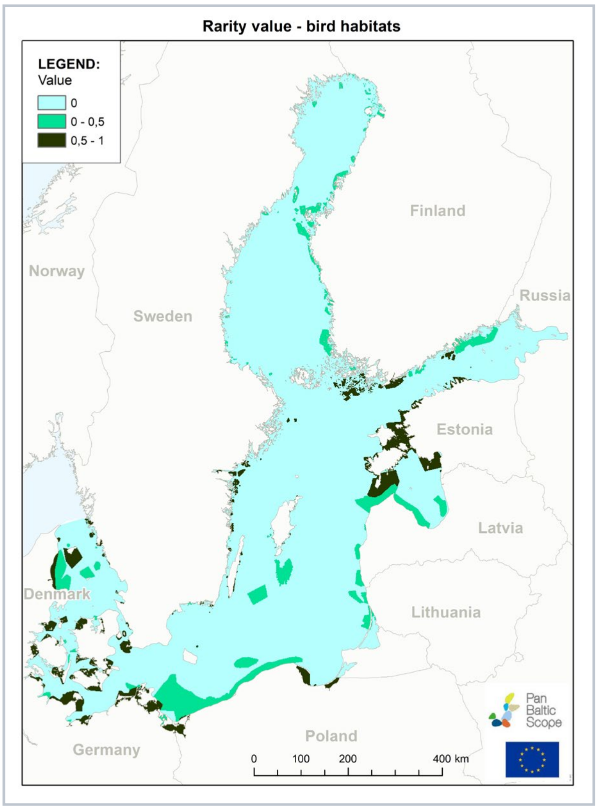


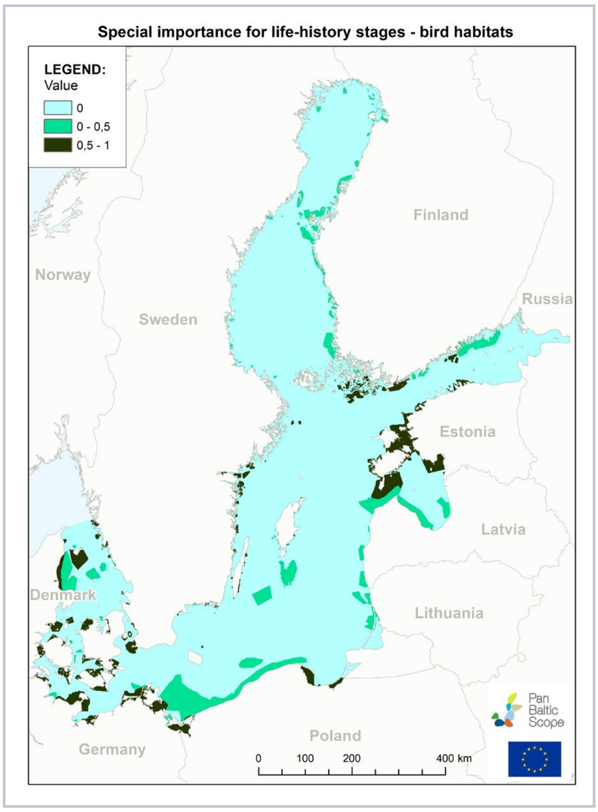
3.2. Ecological value – birds

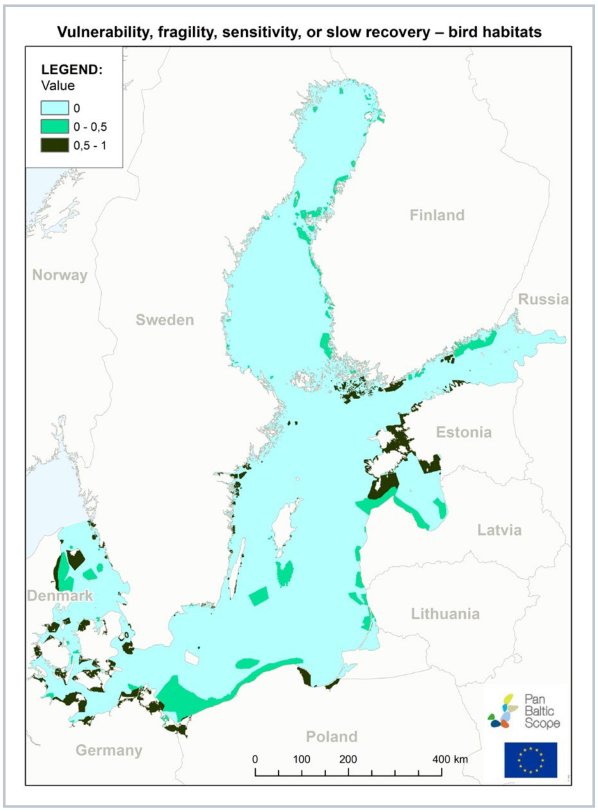





Importance for threatened, endangered or declining bird species
LEGEND:
Value
0
0 - 0,5
0,5 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

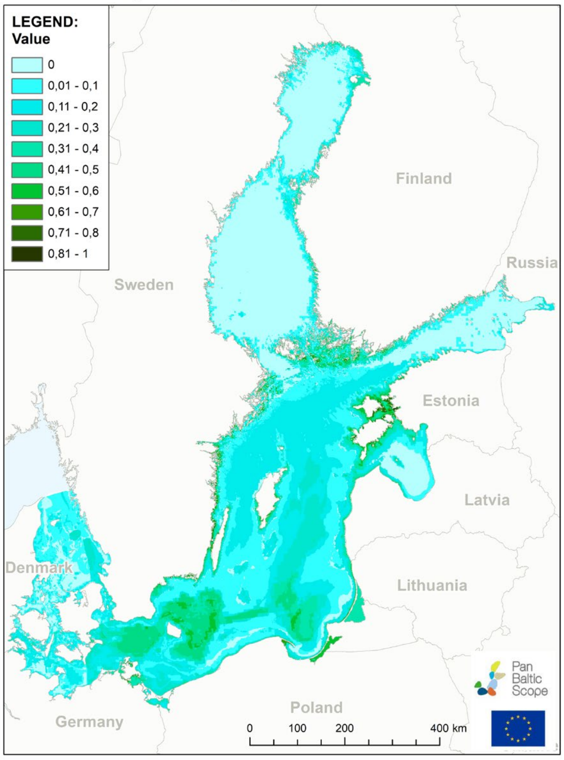

Rarity value - bird habitats
LEGEND:
Value
0
0 - 0,5
0,5 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope


Special importance for life-history stages - bird habitats
LEGEND:
Value
0
0 - 0,5
0,5 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

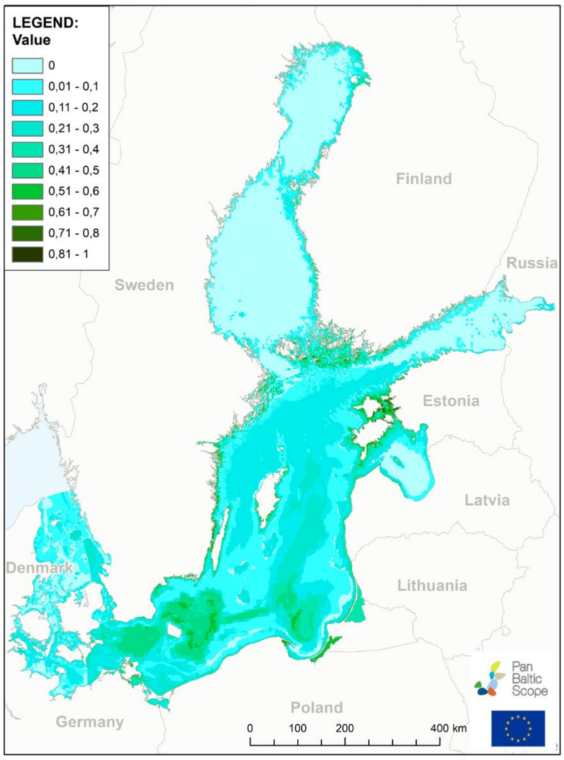

Vulnerability, fragility, sensitivity, or slow recovery – bird habitats
LEGEND:
Value
0
0 - 0,5
0,5 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

3.3. Ecological value – essential fish habitats

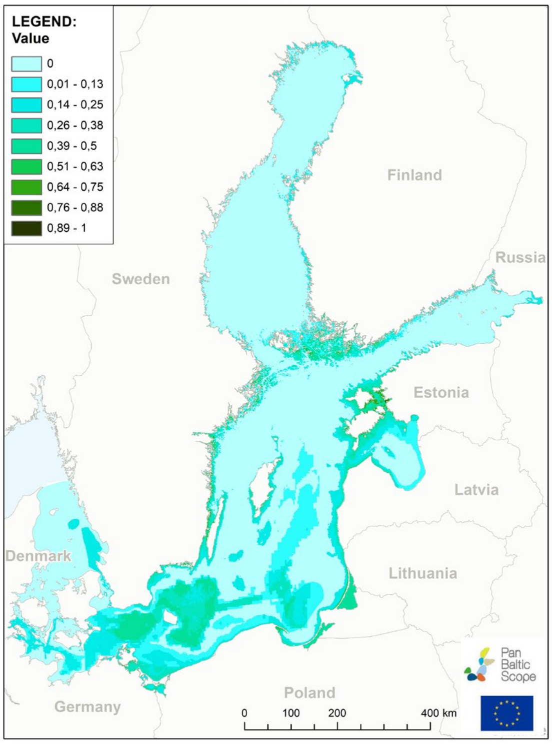
Biological diversity value – essential fish habitats



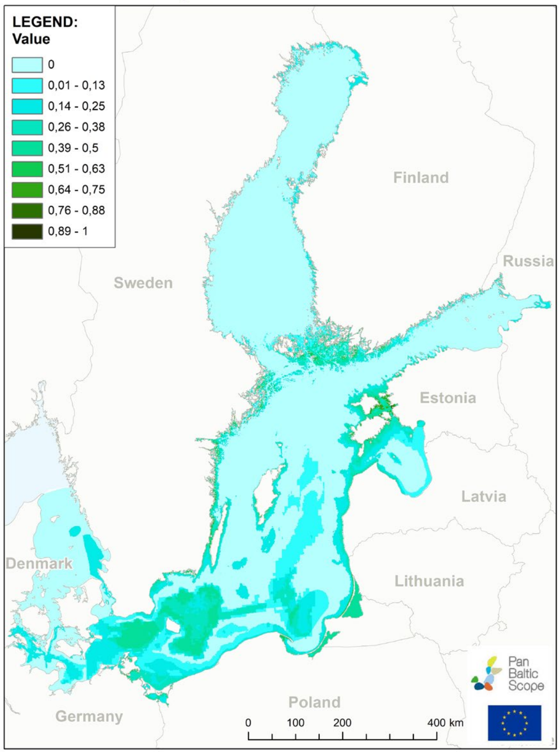
Biological productivity value - essential fish habitats

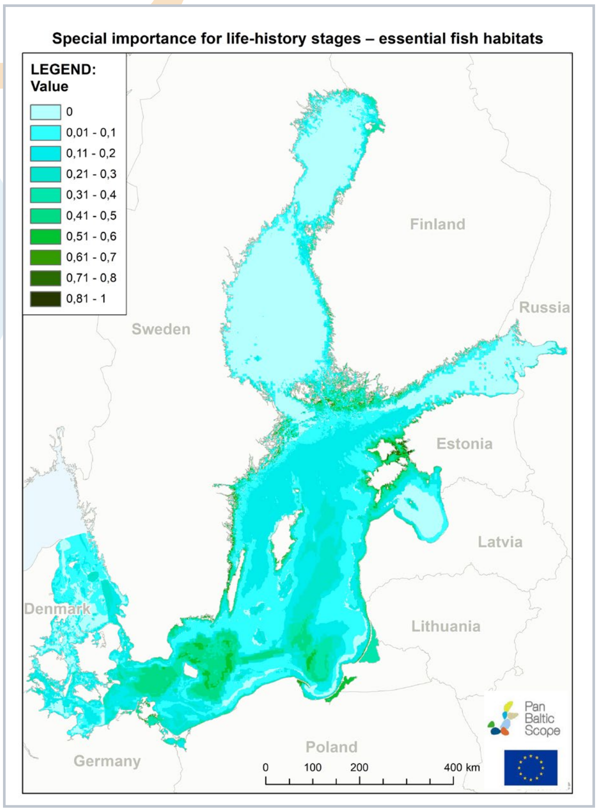


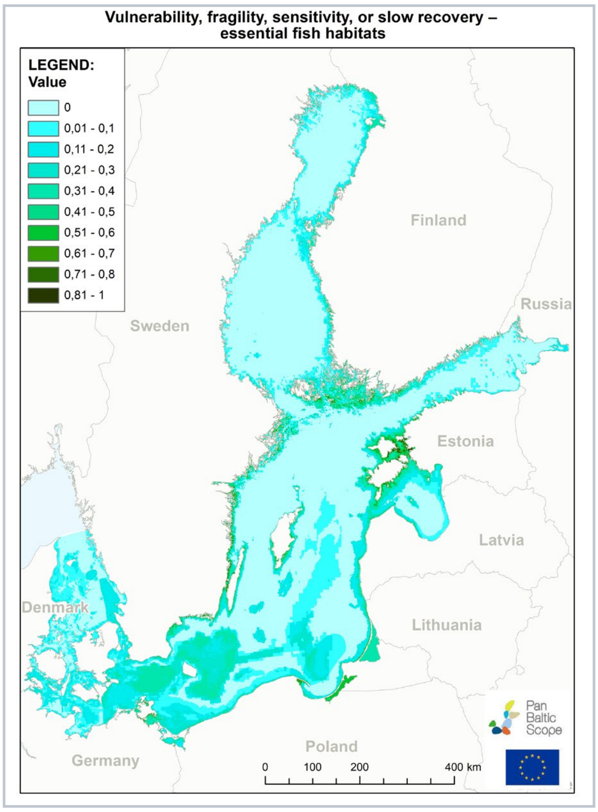
Importance for threatened, endangered or declining essential fish habitats



Rarity value - essential fish habitats

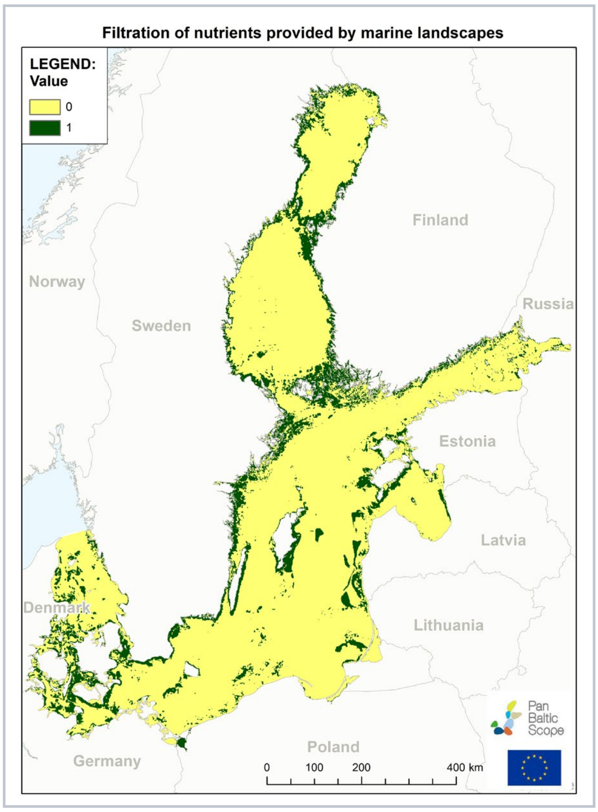


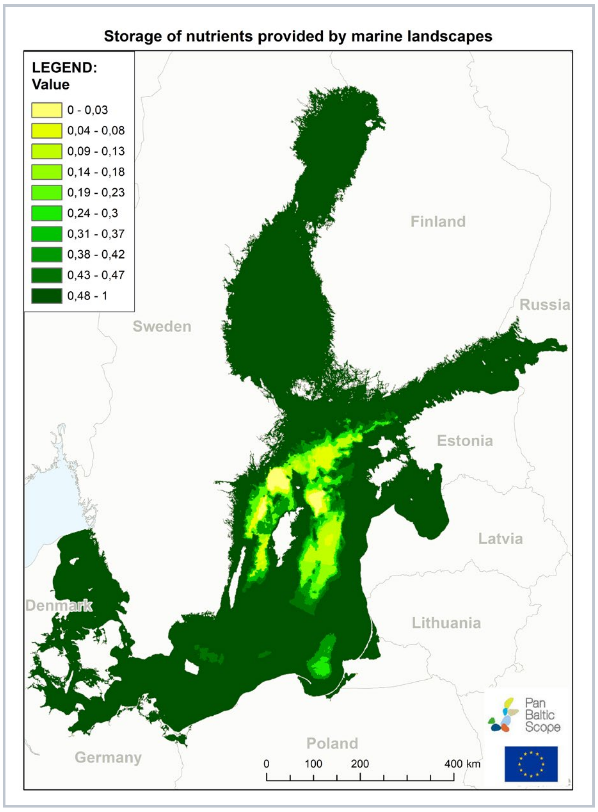


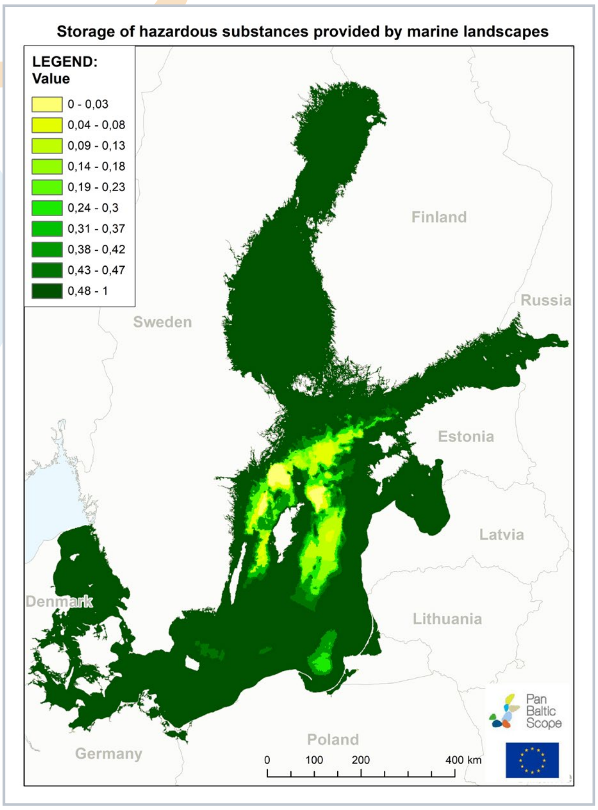


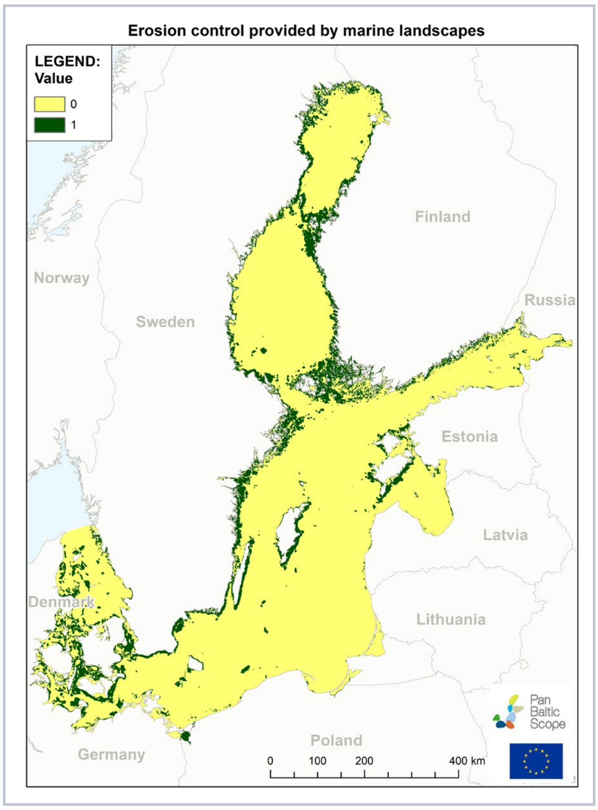
Annex 4: Single ecosystem service maps

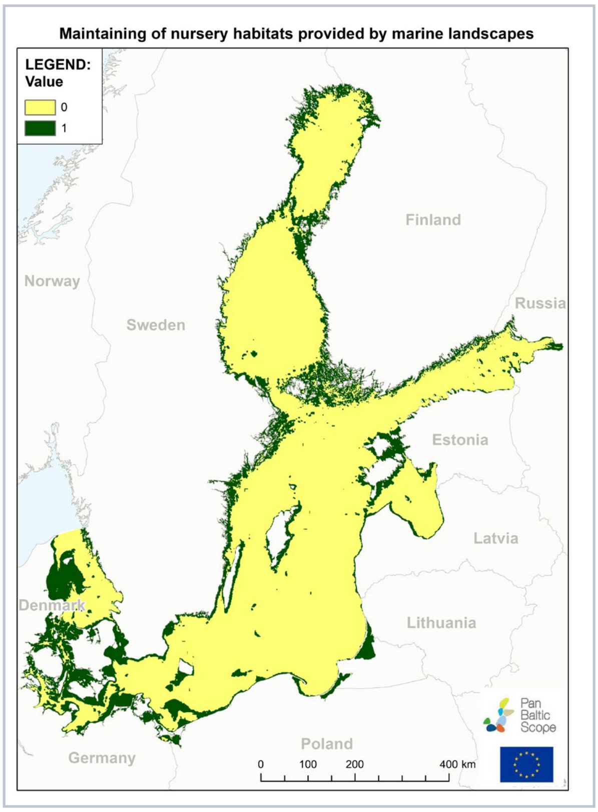
4.1. Ecosystem services provided by marine landscapes

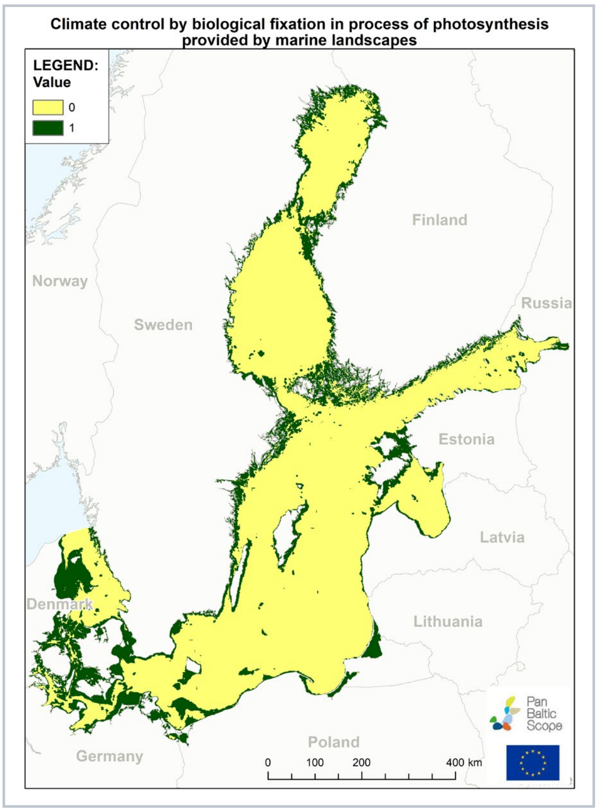


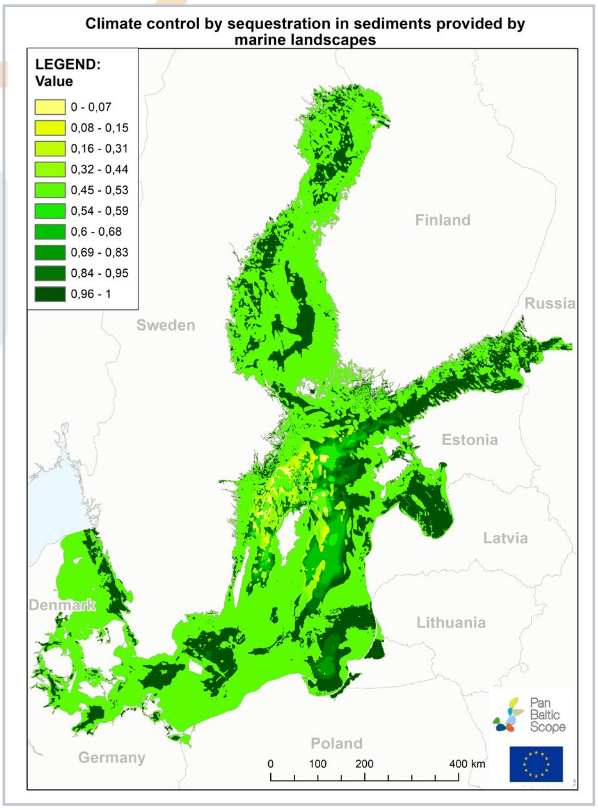


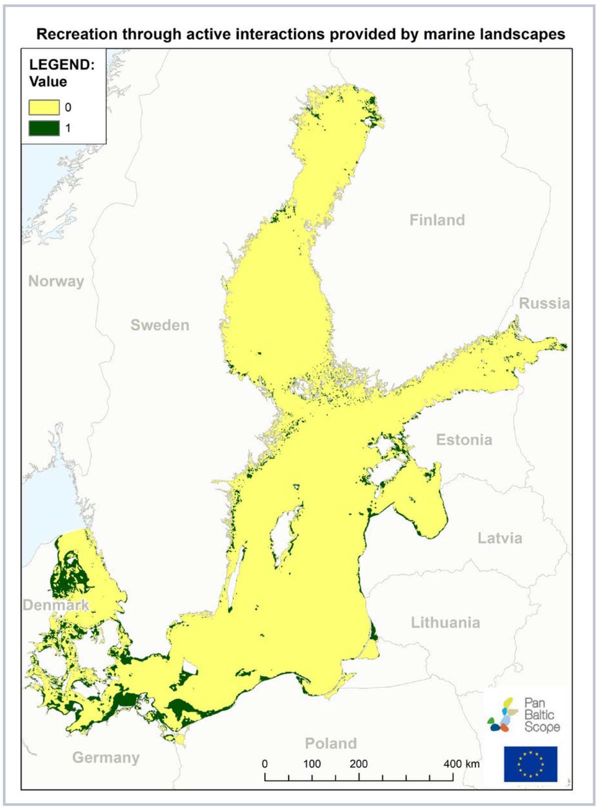

Storage of hazardous substances provided by marine landscapes
LEGEND:
Value
0 - 0,03
0,04 - 0,08
0,09 - 0,13
0,14 - 0,18
0,19 - 0,23
0,24 - 0,3
0,31 - 0,37
0,38 - 0,42
0,43 - 0,47
0,48 - 1
Finland
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

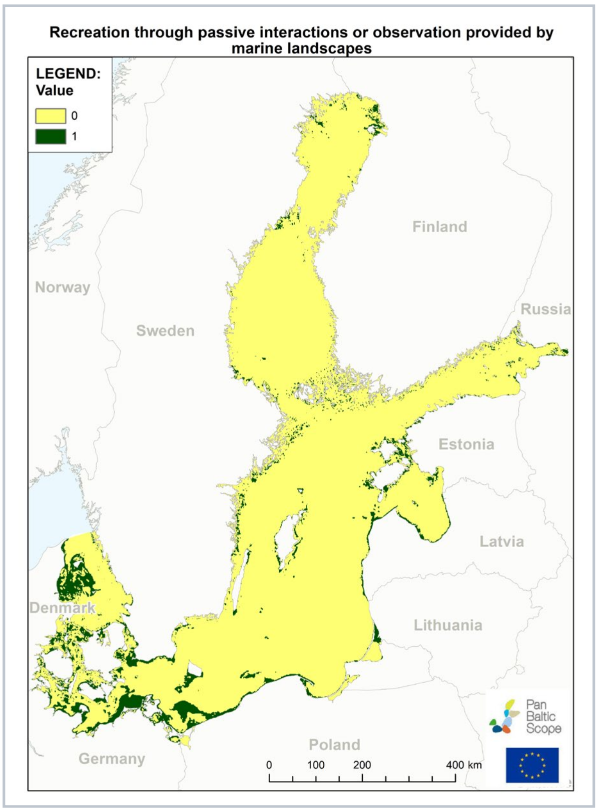

Erosion control provided by marine landscapes
LEGEND:
Value
0
1
Finland
Norway
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope


Maintaining of nursery habitats provided by marine landscapes
LEGEND:
Value
0
1
Finland
Norway
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope


Climate control by biological fixation in process of photosynthesis provided by marine landscapes
LEGEND:
Value
0
1
Finland
Norway
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

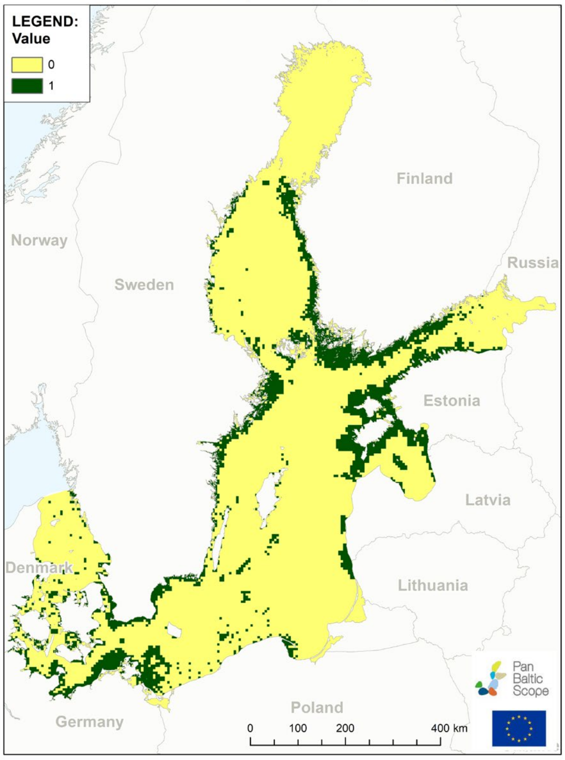

Climate control by sequestration in sediments provided by marine landscapes
LEGEND:
Value
0 - 0,07
0,08 - 0,15
0,16 - 0,31
0,32 - 0,44
0,45 - 0,53
0,54 - 0,59
0,6 - 0,68
0,69 - 0,83
0,84 - 0,95
0,96 - 1
Finland
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope


Recreation through active interactions provided by marine landscapes
LEGEND:
Value
0
1
Finland
Norway
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

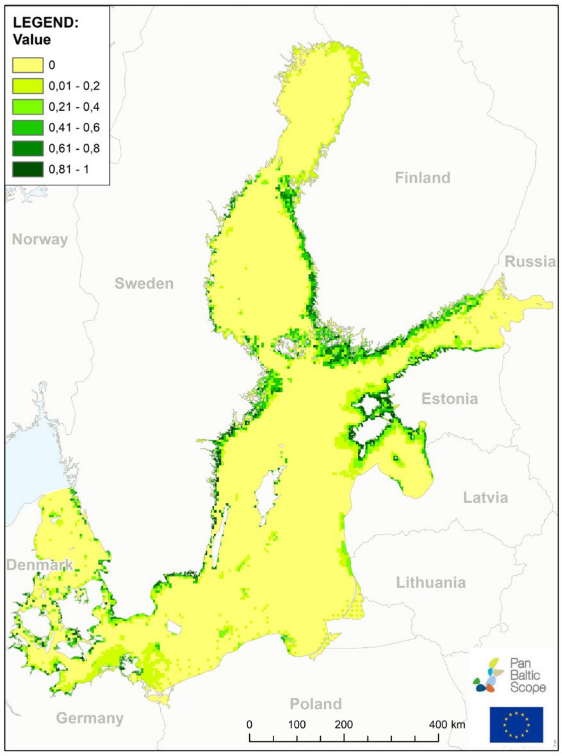

Recreation through passive interactions or observation provided by marine landscapes
LEGEND:
Value
0
1
Finland
Norway
Russia
Sweden
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

4.2. Ecosystem services provided by key benthic species

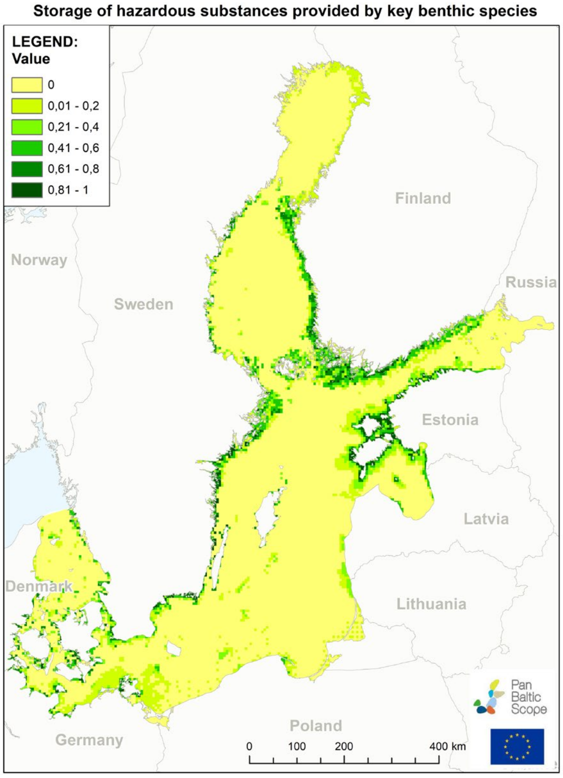
Filtration of nutrients provided by key benthic species



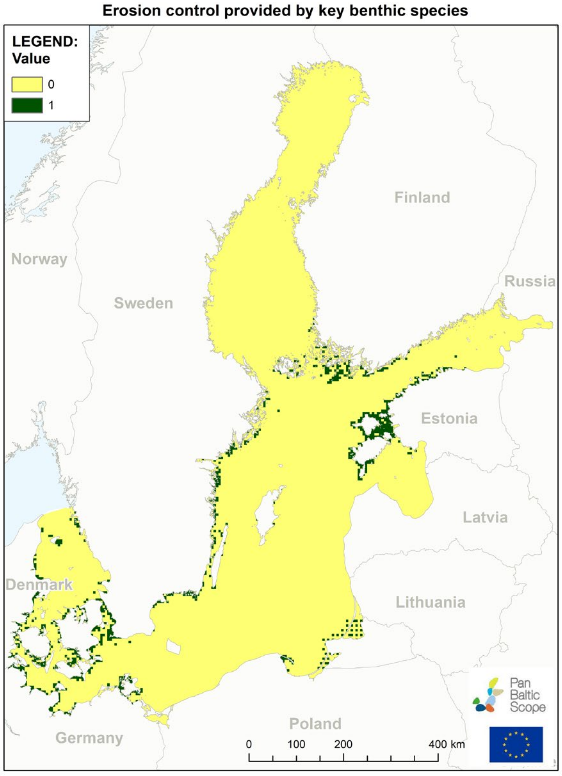
Storage of nutrients provided by key benthic species



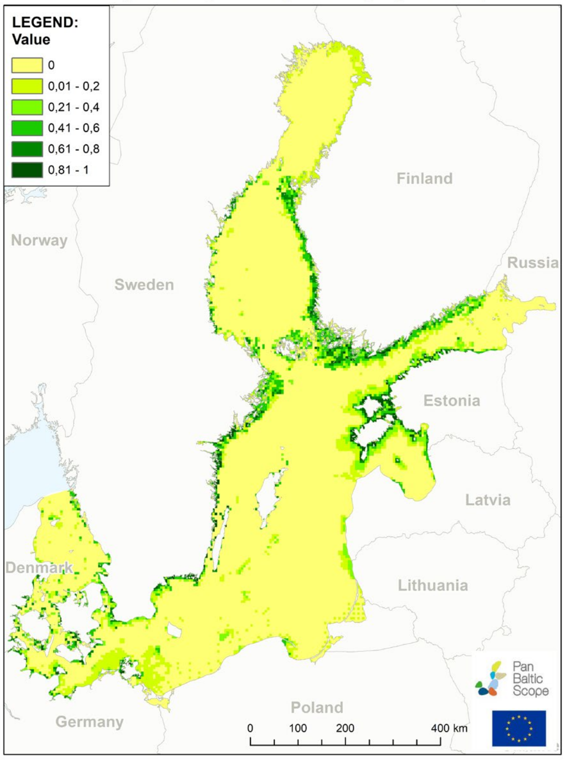
Storage of hazardous substances provided by key benthic species



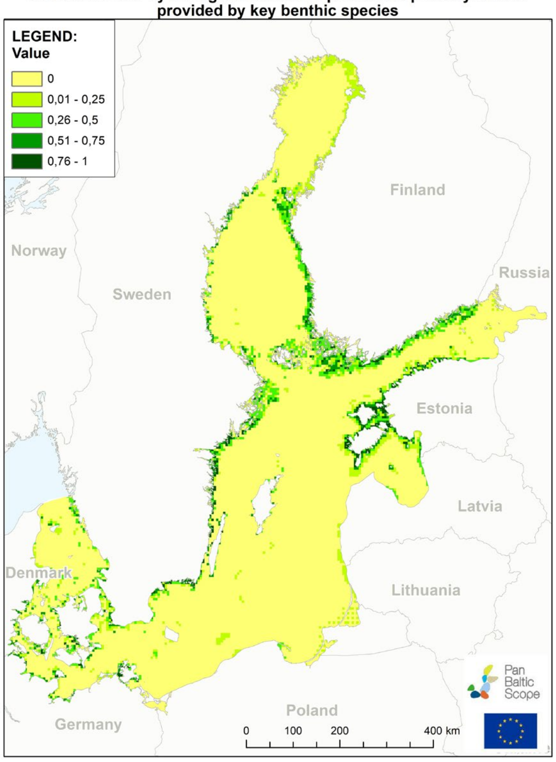
Erosion control provided by key benthic species



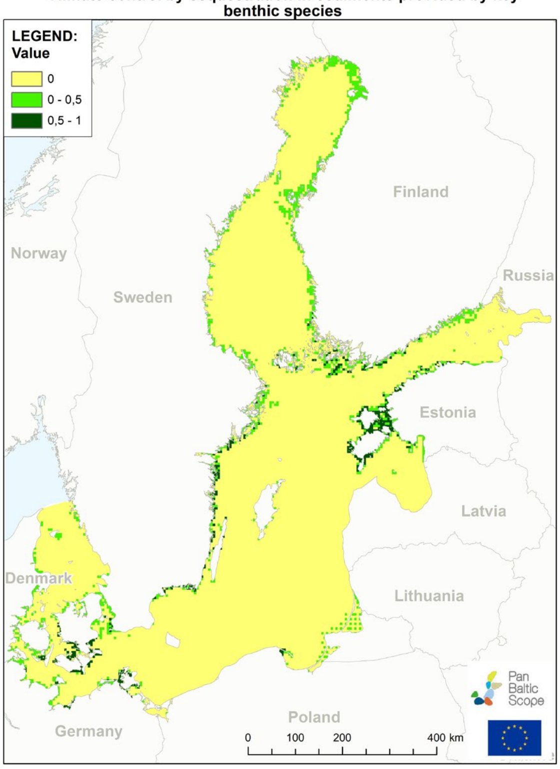
Maintaining of nursery habitats provided by key benthic species



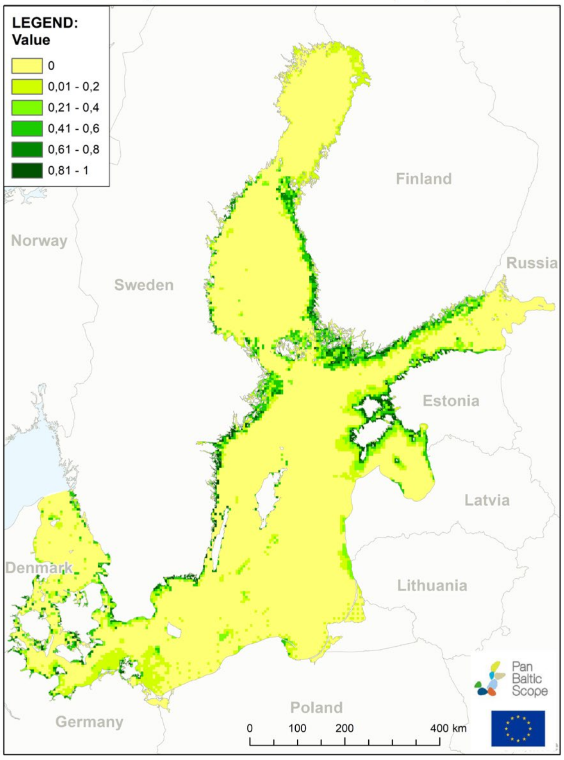
Climate control by biological fixation in process of photosynthesis provided by key benthic species

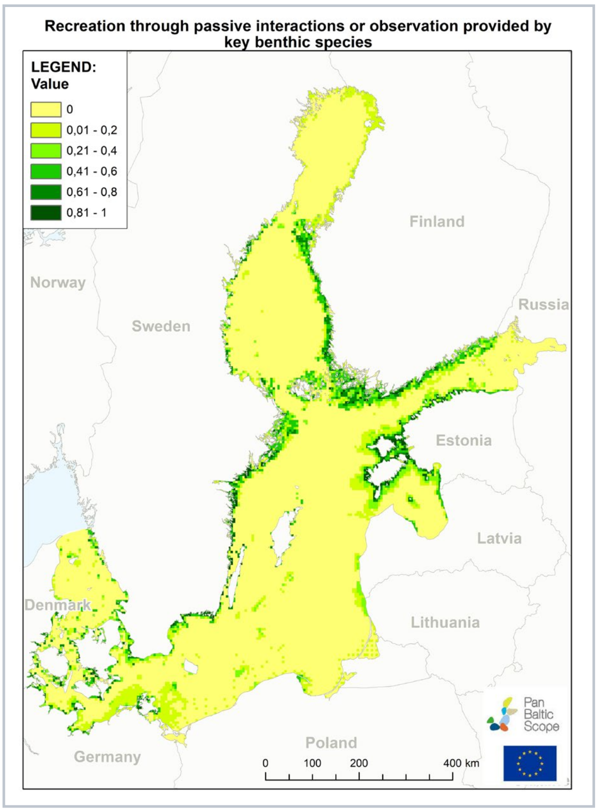


Climate control by sequestration in sediments provided by key benthic species

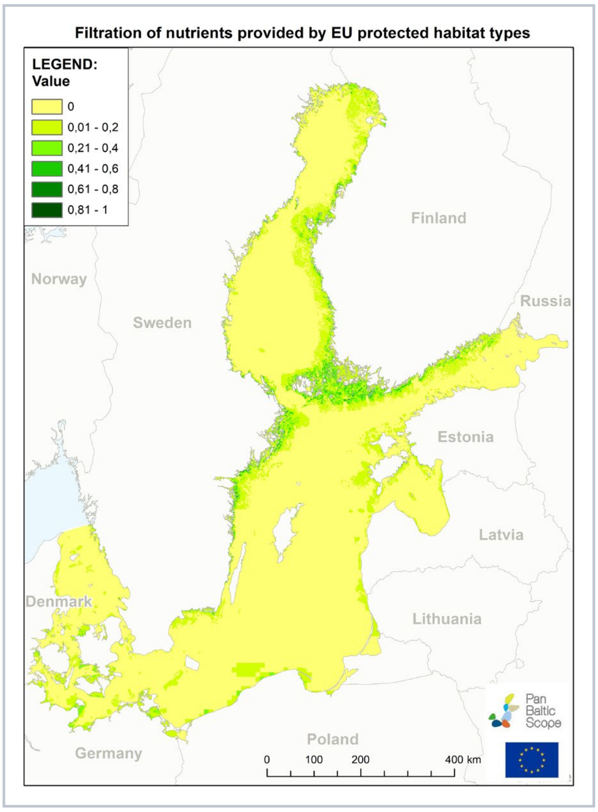


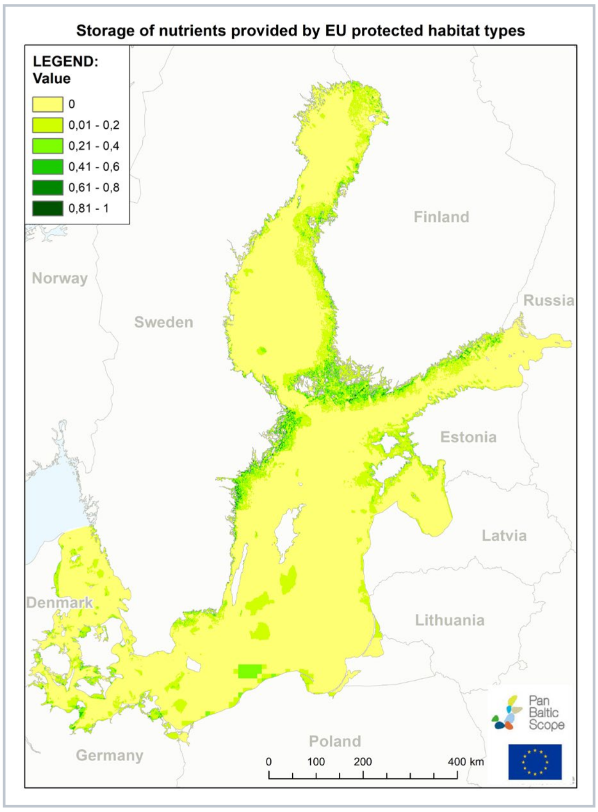
Recreation through active interactions provided by key benthic species

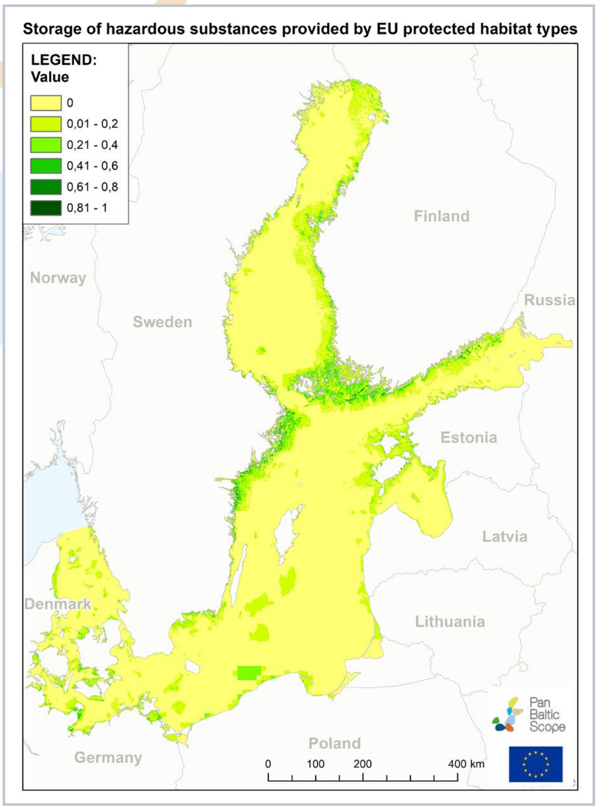


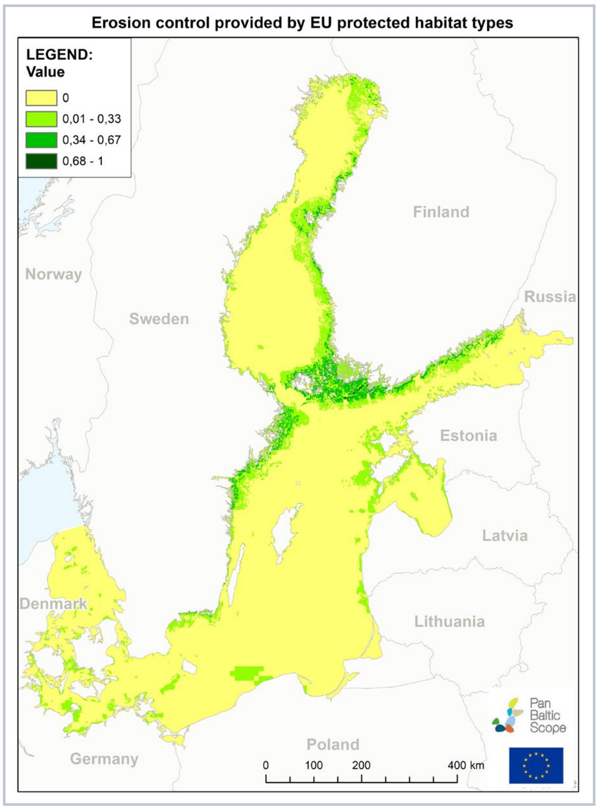


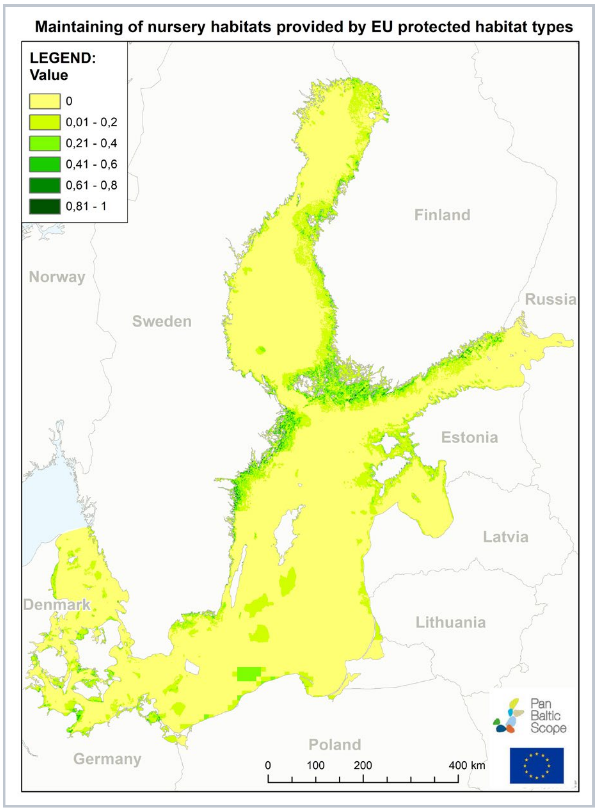
4.3. Ecosystem services provided by EU protected habitats

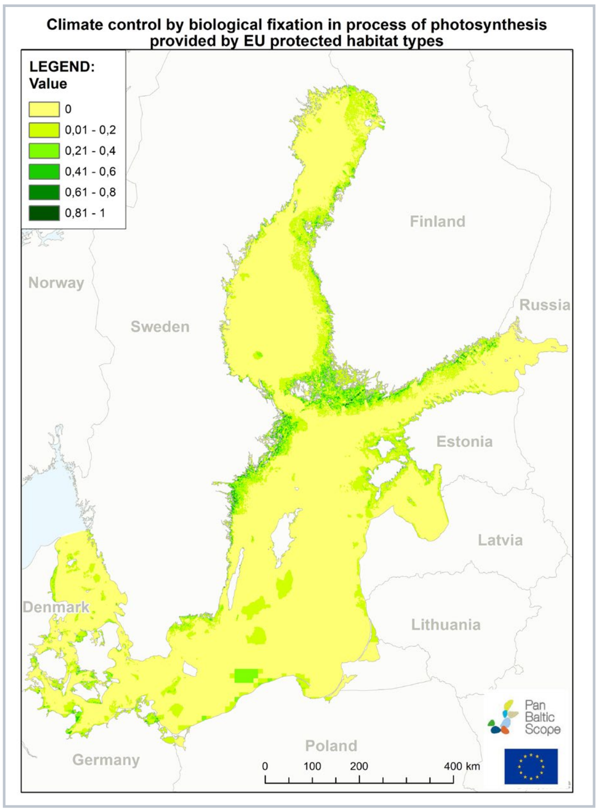


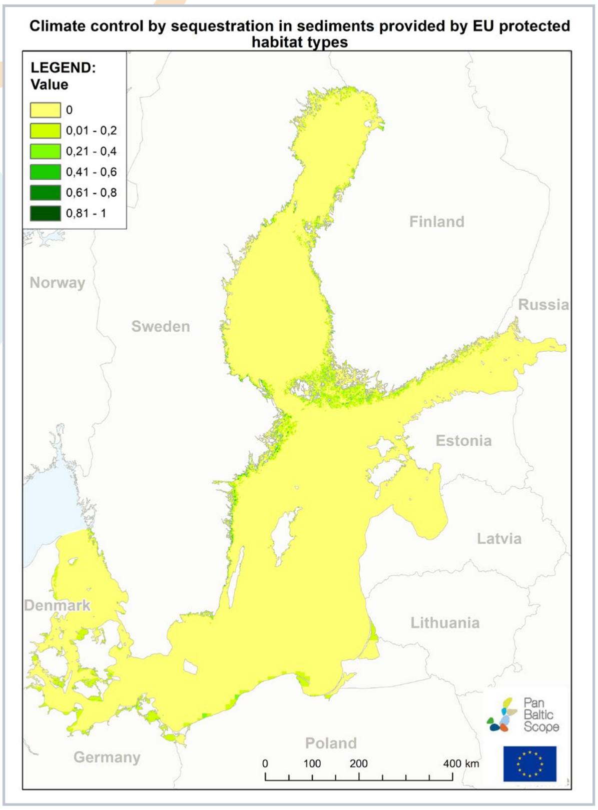


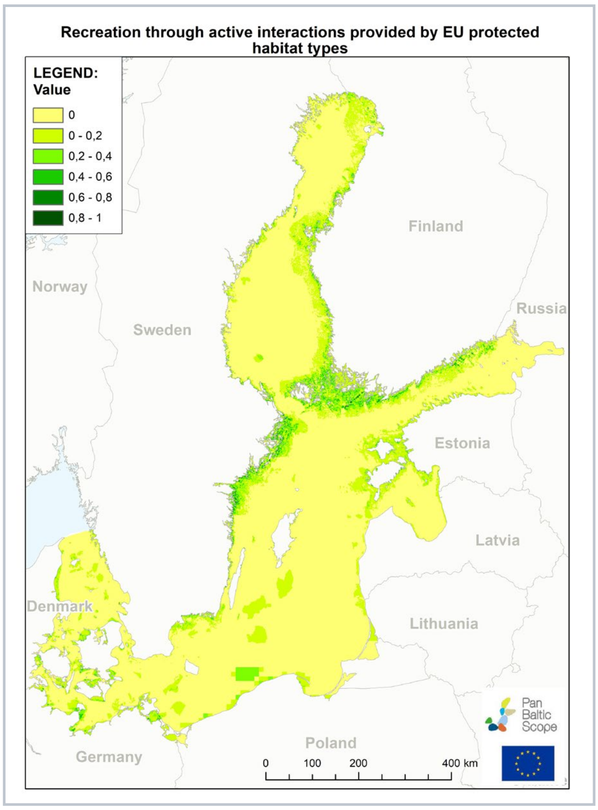

Storage of hazardous substances provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,2
0,21 - 0,4
0,41 - 0,6
0,61 - 0,8
0,81 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

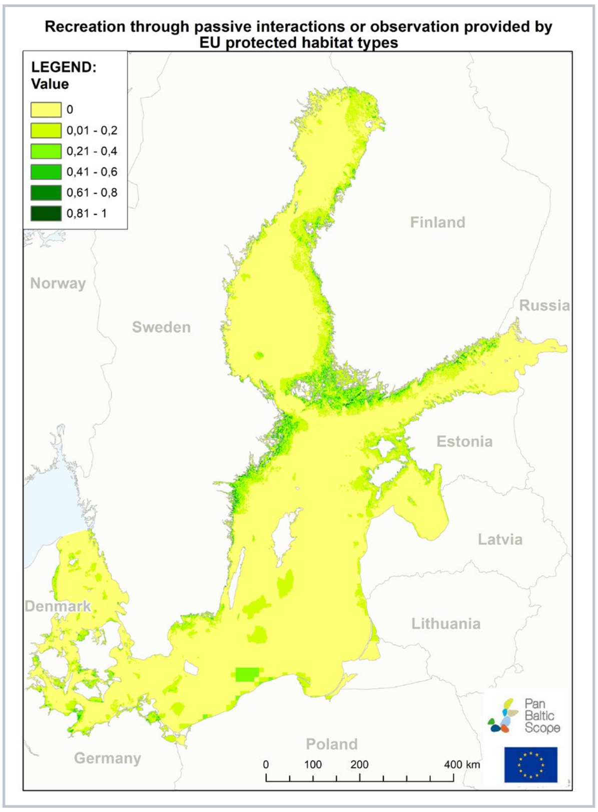

Erosion control provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,33
0,34 - 0,67
0,68 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope


Maintaining of nursery habitats provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,2
0,21 - 0,4
0,41 - 0,6
0,61 - 0,8
0,81 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

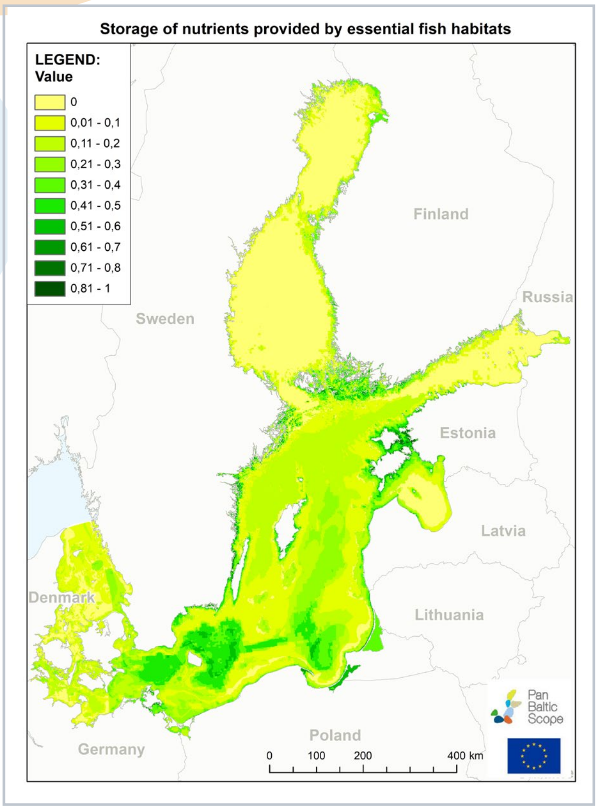

Climate control by biological fixation in process of photosynthesis provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,2
0,21 - 0,4
0,41 - 0,6
0,61 - 0,8
0,81 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0 100 200 400 km
Pan Baltic Scope

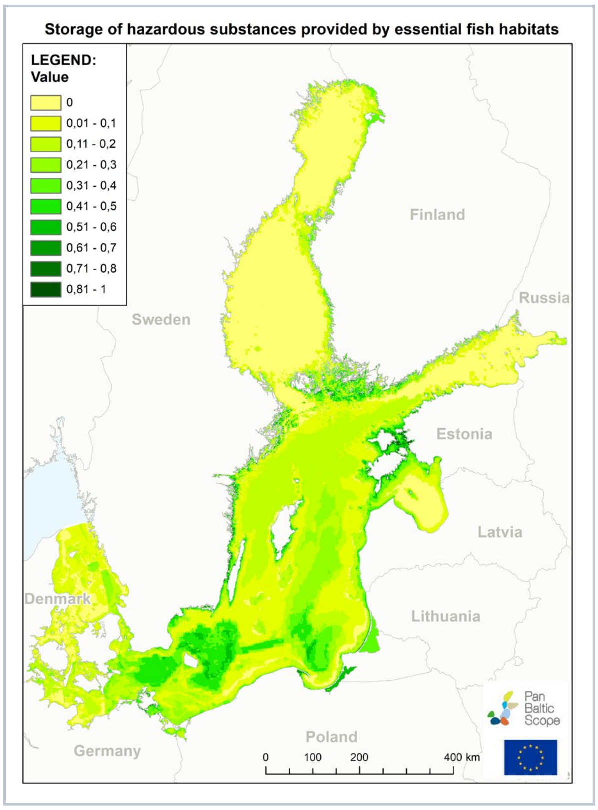

Climate control by sequestration in sediments provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,2
0,21 - 0,4
0,41 - 0,6
0,61 - 0,8
0,81 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

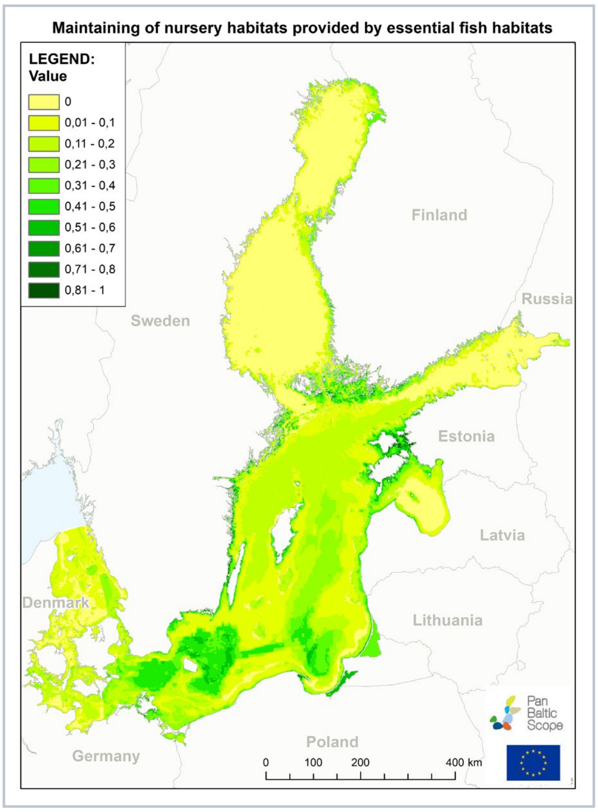

Recreation through active interactions provided by EU protected habitat types
LEGEND:
Value
0
0 - 0,2
0,2 - 0,4
0,4 - 0,6
0,6 - 0,8
0,8 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

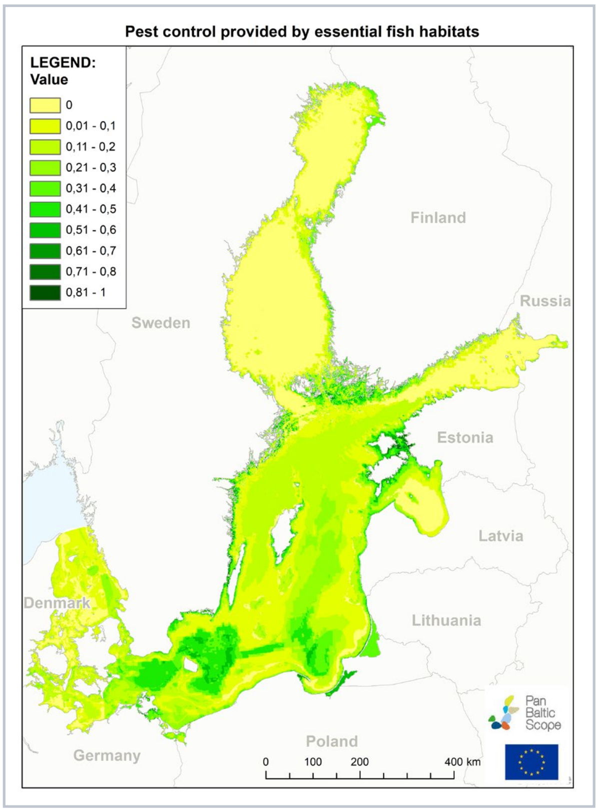

Recreation through passive interactions or observation provided by EU protected habitat types
LEGEND:
Value
0
0,01 - 0,2
0,21 - 0,4
0,41 - 0,6
0,61 - 0,8
0,81 - 1
Finland
Norway
Sweden
Russia
Estonia
Latvia
Denmark
Lithuania
Poland
Germany
0
100
200
400 km
Pan Baltic Scope

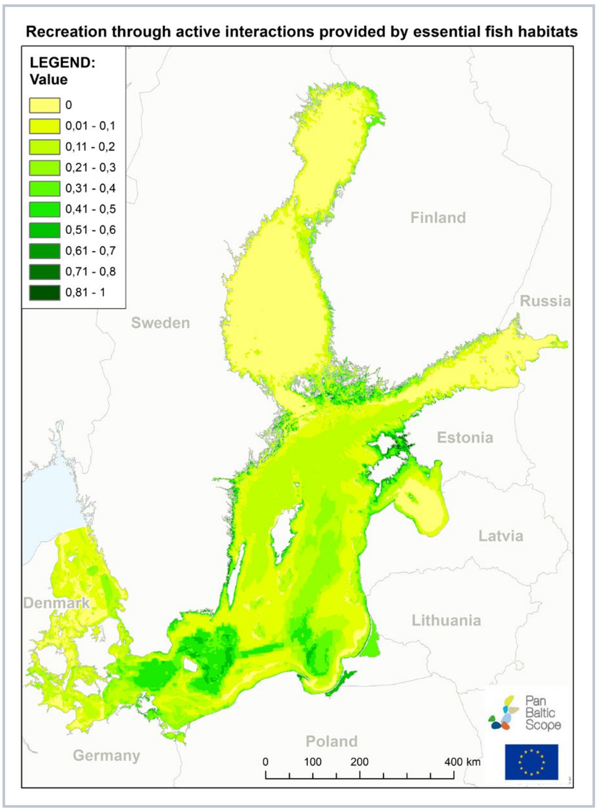
4.4. Ecosystem services provided by the essential fish habitats



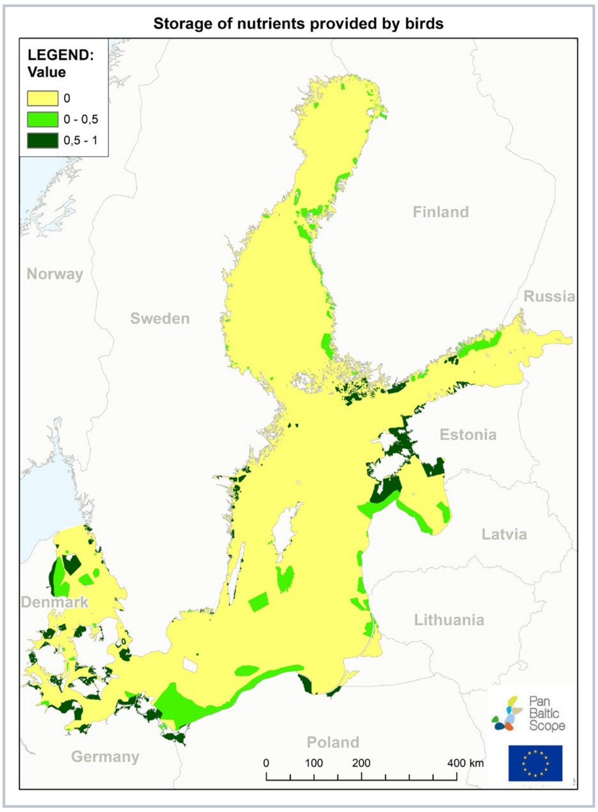


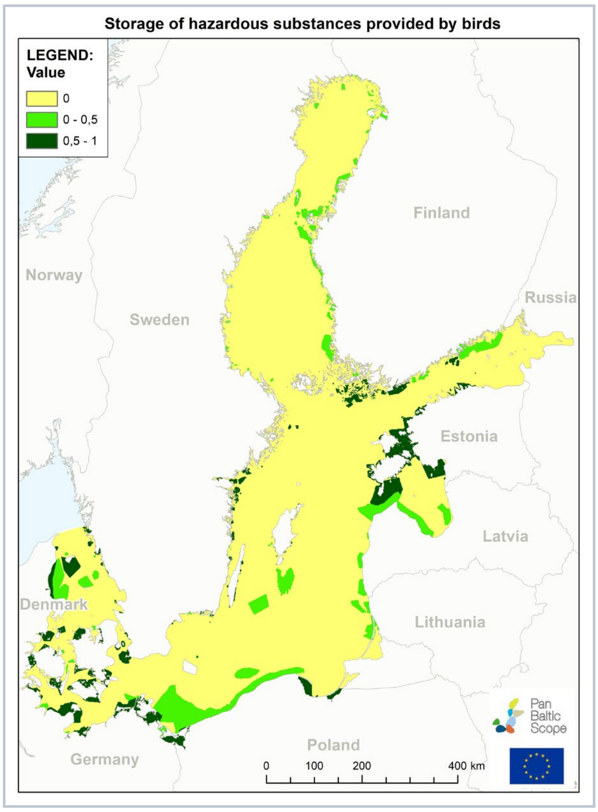




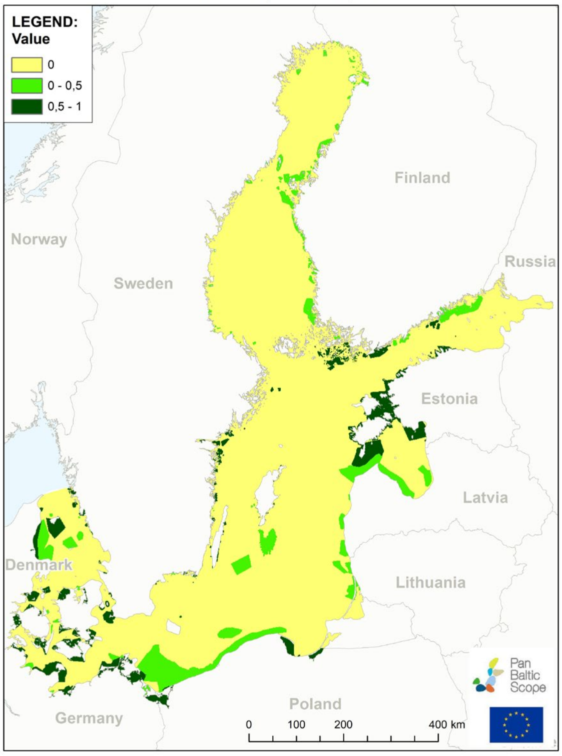


4.5. Ecosystem services provided by bird habitats

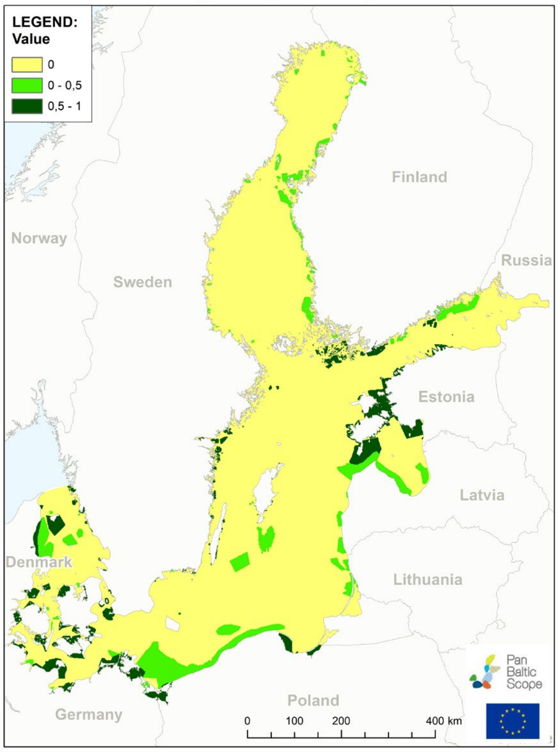




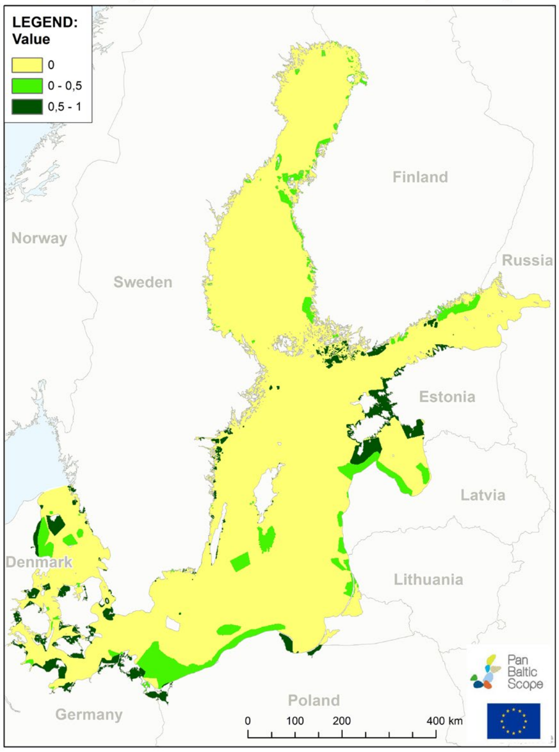
Pest control provided by birds



Recreation through active interactions provided by birds



Recreation through passive interactions or observation provided by birds



Annex 5: Testing the Pan Baltic Scope approach to GI mapping at national scale: Latvian case study

Following the methodology developed in the Pan Baltic Scope project, the application and mapping of GI was carried out in the Latvian case study. The Pan Baltic Scope approach includes four steps and they all were applied to develop the GI example map for the LV case study.

The first step includes the identification of the components forming the marine GI and the selection of suitable data sets for mapping. Similarly to the entire Baltic Sea, the aggregation of ecosystem components spatial data layers for Latvian waters has been carried out for the benthic habitats, birds and fish using the available datasets. A dataset on mammal distribution was not included for the same reason as it is described for the Baltic sea example. The ecosystem components identified for Latvian waters are listed in Table 1. Unlike the aggregated ecological value map of the Baltic Sea, the data coverage used for Latvian waters is more accurate than what is available in HELCOM Maps and Data services.

Table 1. Data sets of the ecosystem components used for LV case study

Ecosystem component	
Benthic habitats	Circalittoral hard bottom
	Circalittoral sand
	Circalittoral mud
	Circalittoral mixed
	Reefs (1170)
Habitat building species	*Furcellaria lumbricalis*
	Mytilus sp.
	Fucus sp.
Mobile species and they key habitats	Essential fish habitats developed within Pan Baltic Scope
	Wintering seabirds
	Breeding seabird colonies

The second step is mapping areas of high ecological value. The detailed methodology for assessing and mapping ecologically valuable areas of marine waters is described in report chapters 3.2.1 and 3.2.2. According to the methodology, the ecosystem components were assessed against the six criteria and combined ecological value maps of three groups of the ecological components were obtained (Figure 1).

The results of the overall aggregated ecological value map for the Latvian case study are presented in figure 2. Overall ecological value maps strongly depend on the information available for the analysis. For example, marine protected areas have been designated in the territorial waters of Latvia based on data on important bird areas. Based on the need to develop a nature protection plan for these areas, a detailed mapping of their biological values (birds, benthos, fish) has been carried out. As a result, the map shows a relatively higher ecological value within MPAs compared to adjacent areas.

Fig. 1. Results of aggregated ecological value maps for three groups of ecosystem components: benthic habitats, essential fish habitats and birds

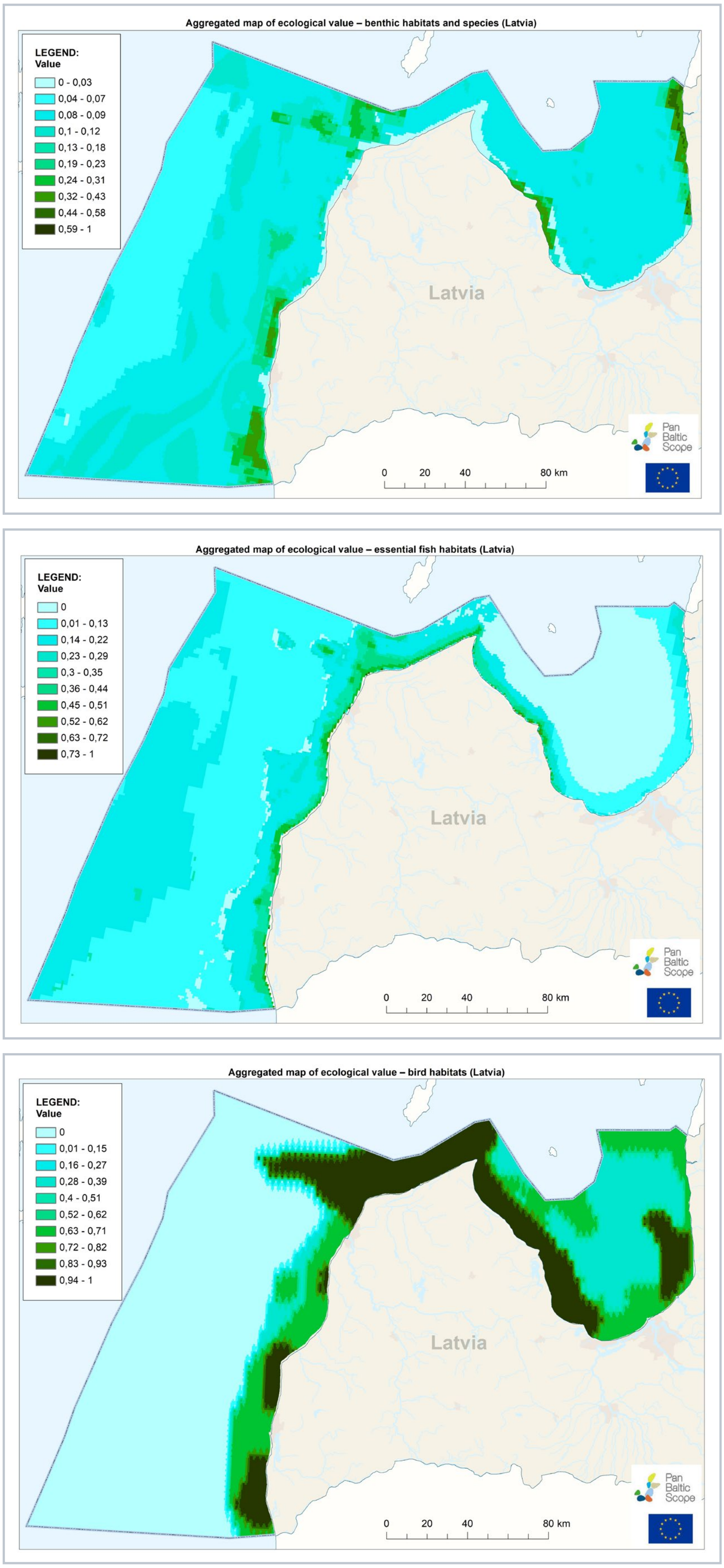
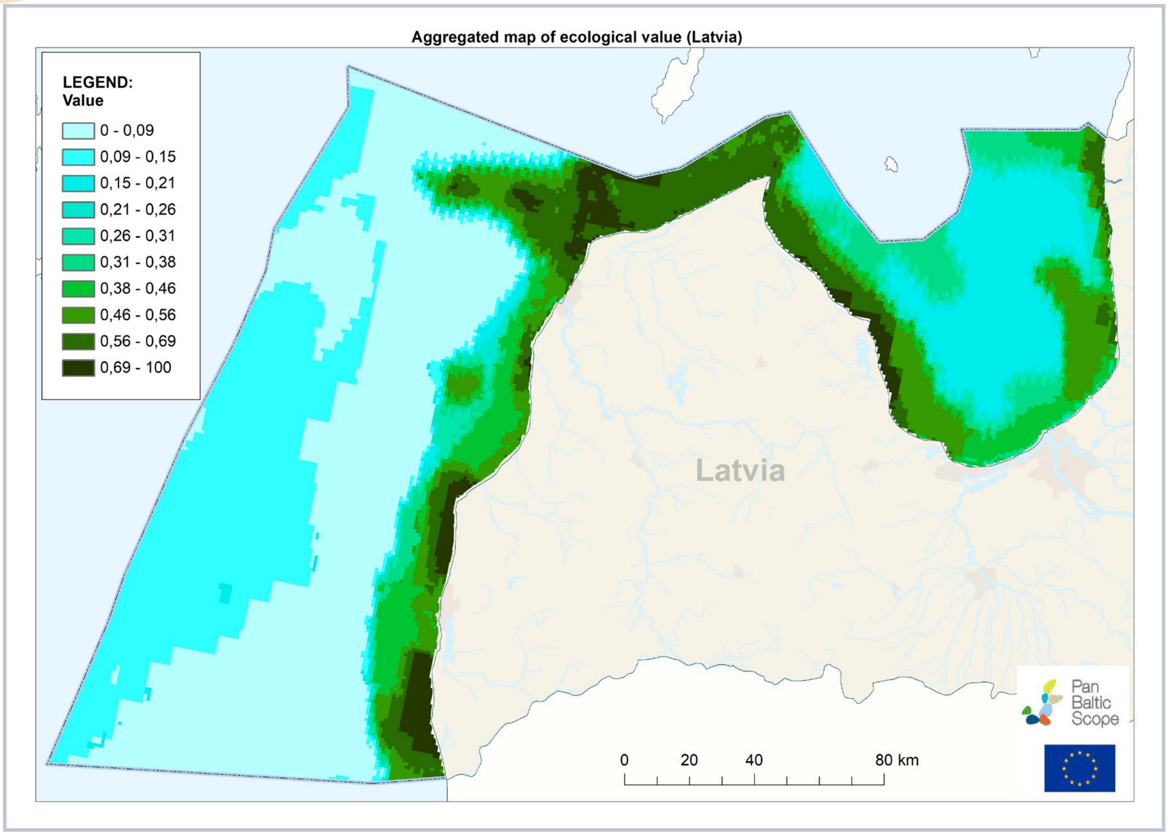


Fig. 2. Map indicating the areas of high ecological values in Latvian waters.



The third step is mapping the ecosystem service supply potential, which includes assessment of the identified marine ecosystem components of the Latvian case study against selected ecosystem services. The ecosystem services potentially relevant for mapping of marine GI and the detailed methodology for assessing the ecosystem service supply potential of marine areas are described in report chapters 3.3.1 and 3.3.2. The aggregated map of the ecosystem service supply potential in the Latvian case study area is presented in figure 3.

The final step includes aggregation of the results from the mapping of areas of high ecological value and ecosystem services supply potential to indicate the areas potentially forming marine GI. The final GI mapping results for the Latvian case study are shown in figure 4.

The development of the GI map strongly depends on the level of information detailedness. When using the GI mapping results, it should be understood that they also reflect the lack of information about the territory of the exclusive economic zone. Obtaining the missing information and presenting it on the ecological value and ecosystem service supply potential maps could significantly change the aggregated GI map. Therefore, it is necessary to regularly update the GI map with new information and to review the situation in already mapped areas.

Fig. 3. Aggregated map of the ecosystem service supply potential.

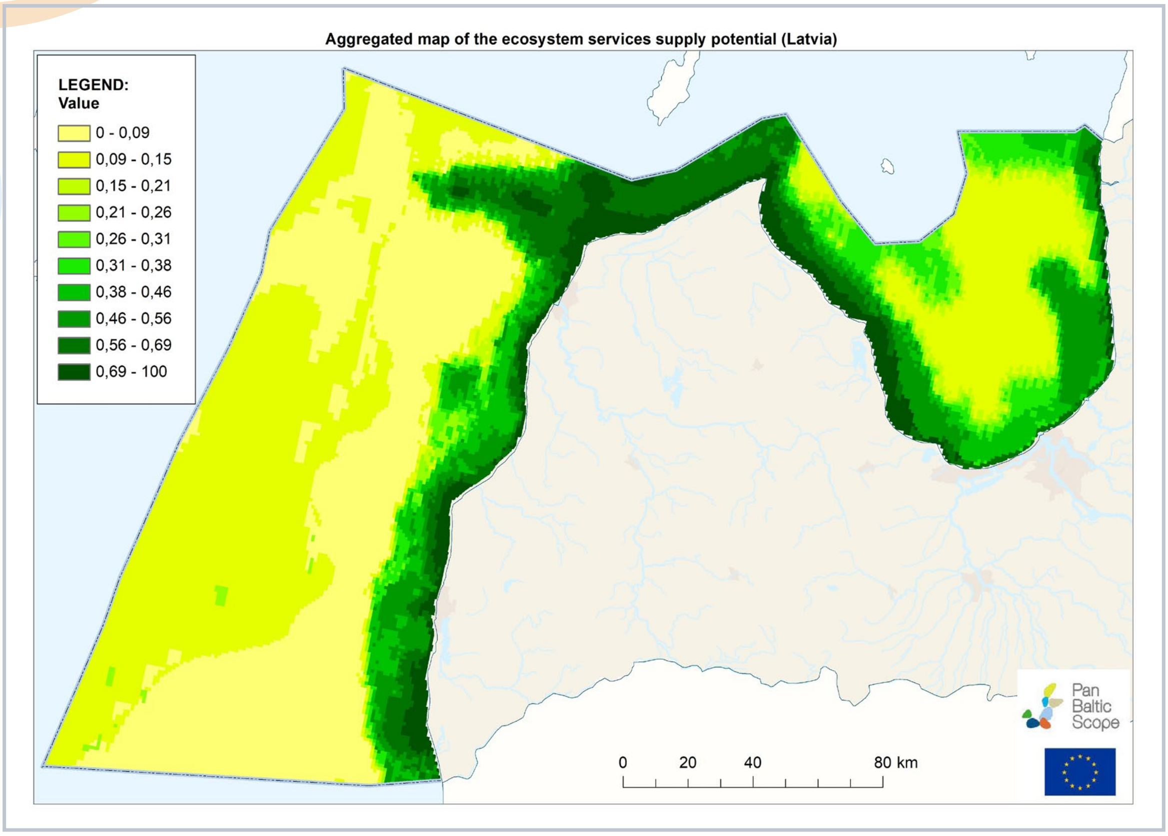
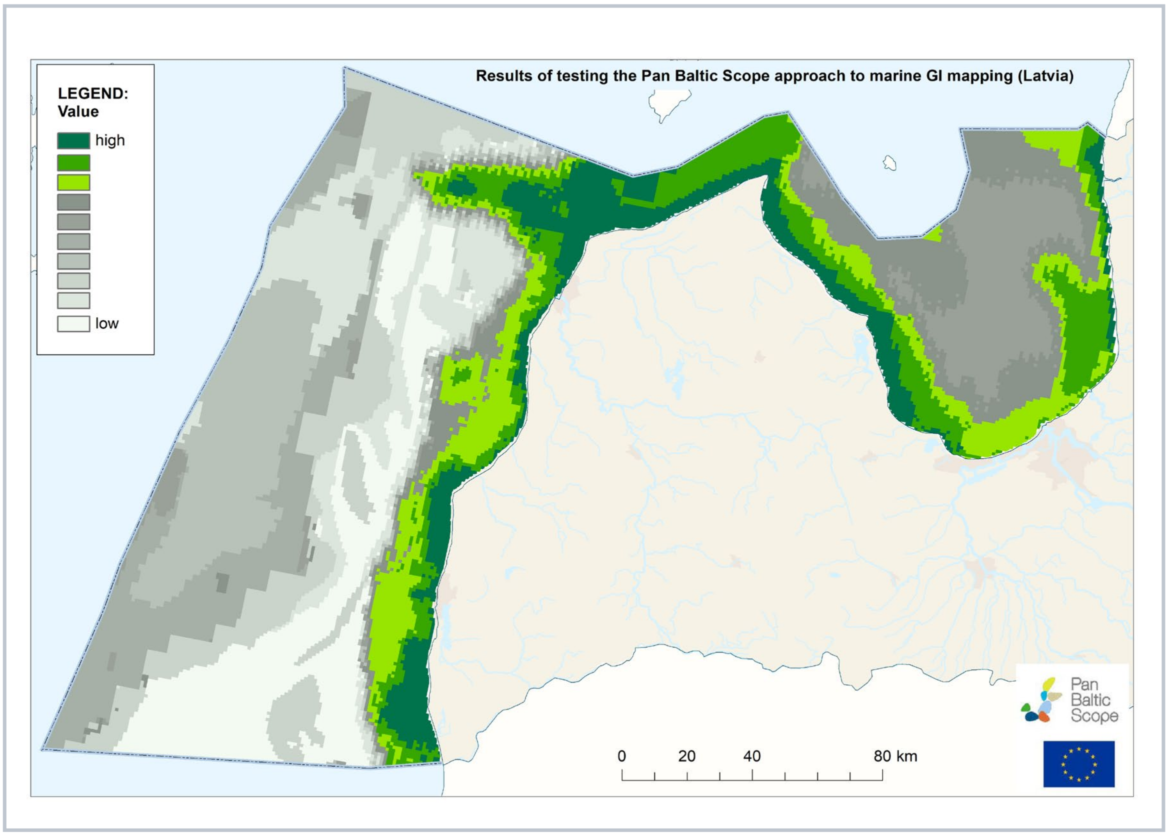


Fig. 4. Areas of high ecological value and high potential of ecosystem service supply.



Pan Baltic Scope focuses on cross-border collaboration and has three interlinked work packages with 12 activities.

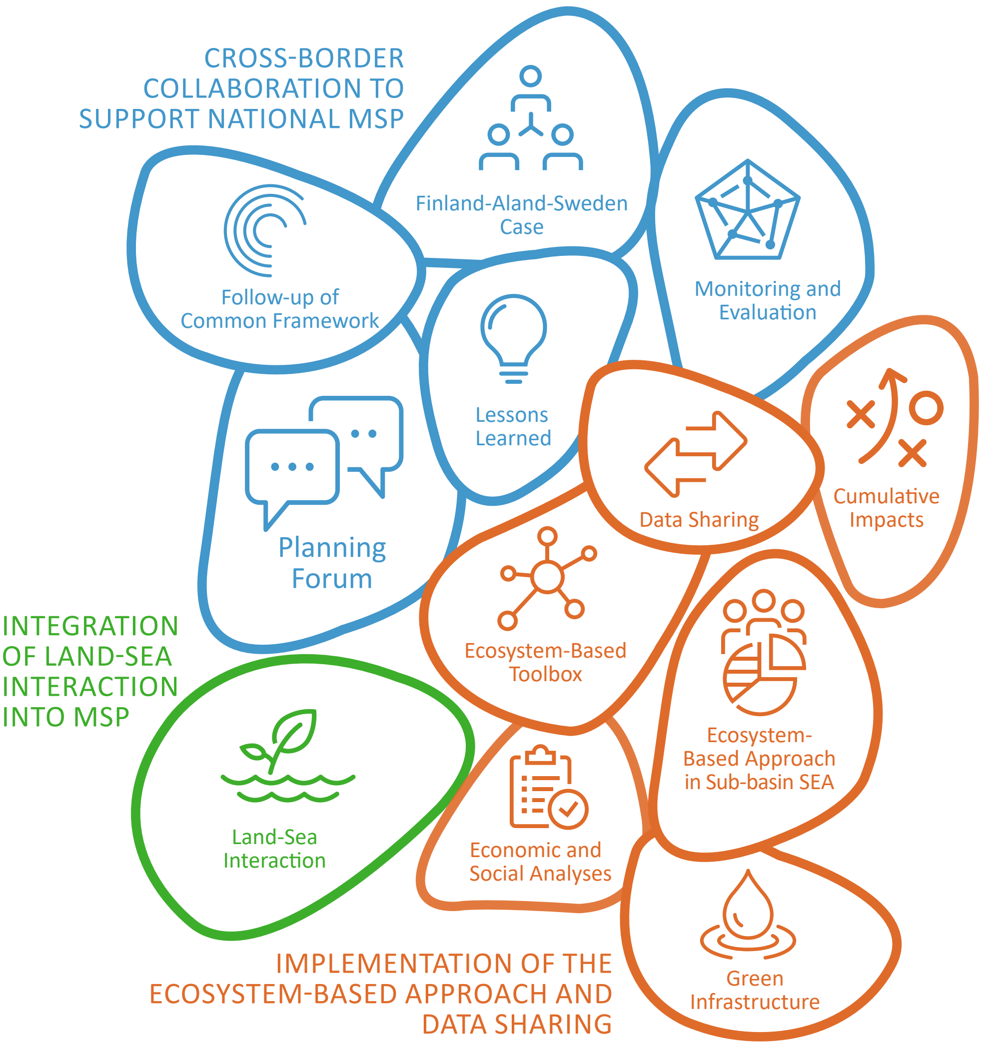
We establish a Planning Forum as the central platform for our collaboration on specific planning issues identified by the planning authorities and regional organisations.

We carry out concrete cross-border activities at different geographical levels to meet the needs of the national maritime spatial planning processes and to support the successful implementation of the EU MSP Directive.

We develop **tools and approaches** at pan-Baltic level, to contribute to coherent maritime spatial plans in the Baltic Sea Region, including:

- implementation of an ecosystem-based approach;
- cumulative impacts;
- green infrastructure;
- socio-economic analyses.

We establish a Planning Forum as the central platform for our collaboration on specific planning issues identified by the planning authorities and regional organisations.
We carry out concrete cross-border activities at different geographical levels to meet the needs of the national maritime spatial planning processes and to support the successful implementation of the EU MSP Directive.



The Pan Baltic Scope project has developed a concept of marine green infrastructure (GI), defining it 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 project has tested GI mapping at the scale of the Baltic Sea, covering the two essential aspects - identification of areas of high ecological value and potential supply of ecosystem services. The report gives an overview of the concept of GI, explores the existing approaches to GI mapping, describes the methodology developed by the Pan Baltic Scope project for marine GI mapping as well as concludes about the future research needs and opportunities to apply this information in the MSP process.

Pan Baltic Scope is a collaboration between 12 planning authorities and organisations from around the Baltic Sea. We work towards bringing better maritime spatial plans in the Baltic Sea Region.

Co-funded by the European Maritime and Fisheries Fund of the European Union

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