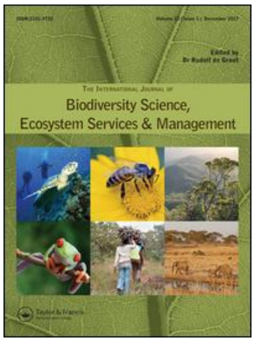

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SPECIAL ISSUE: MARINE & COASTAL ECOSYSTEM SERVICES

Application of the marine ecosystem services approach in the development of the maritime spatial plan of Latvia

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ABSTRACT
The Maritime Spatial Plan for Internal Waters, Territorial Waters and Economic Exclusive Zone of the Republic of Latvia is a long-term spatial planning document, which defines the permitted uses of the sea and conditions for development. Work on maritime spatial planning (MSP) in Latvia was a novel process from different aspects including incorporation of the concept of ecosystem services (ES) into MSP. In the course of the MSP process, marine ES were mapped and assessed, and impacts of proposed spatial solutions for the use of the sea were assessed. The scope of mapping and assessment of ES was limited by data availability and expert knowledge on marine ecosystems. MSP in Latvia was an open and transparent process with an active involvement of different stakeholder groups. Marine ES assessment results were visualized and used during the public consultations to highlight the marine areas providing the most significant social benefits as well as to facilitate debate about potential impacts arising from proposed uses of the sea. The marine ES approach, in a spatially explicit manner, provided stakeholders and policymakers with a strategic framework to address a complex social–ecological system.

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Ecosystem services; maritime spatial planning; impact assessment; Latvia; Baltic Sea

1. Introduction

Comprehensive marine planning is a process used to define a coherent and more efficient use of marine space and resources. With the adoption of the Maritime Spatial Planning (MSP) Directive (Directive 2014/89/EU), Member States of the European Union are required to establish a formal process by which human activities in marine areas are organized and managed to achieve ecological, economic and social objectives (EU 2014). The necessity to organize human activities in marine areas arose from the growing competition between economic interests, such as maritime transport, offshore energy, port development, fisheries and aquaculture together with social and environmental concerns (Douvere and Ehler 2009; Domínguez-Tejo et al. 2016). Nowadays it is widely recognized that 'healthy marine ecosystems and their multiple services, if integrated in planning decisions, can deliver substantial benefits in terms of food production, recreation and tourism, climate change mitigation and adaptation, shoreline dynamics control and disaster prevention' (EU 2014, recital 13). The contribution of healthy marine ecosystems to human well-being has been demonstrated by several research studies published over the last decades (e.g. Holmlund and Hammer 1999; Worm et al. 2006; Outeriro and Villasante 2013; Börger et al. 2014). At the same time, human activities (e.g. – shipping and fisheries, marine aquaculture, mineral and oil extraction, off-shore constructions including wind-farms) and related pressures (e.g. marine pollution and habitat destruction, marine invasive species, etc.), together with nutrient runoff from land, are impacting the structure and function of marine ecosystems and consequently reduce their capacity to provide ecosystem services (ES) (Lotze et al. 2006; Halpern et al. 2012; Outeriro and Villasante 2013; Rivero and Villasante 2016).

MSP is a decision-making process that applies scientific data and geospatial information to address conflicts and organize human activities in order to avoid negative impacts on marine health, functions and services (Center for Ocean Solutions 2011). Thus, integration of ES assessment in both MSP and in the strategic environmental assessment (SEA) of maritime spatial plans can support the sustainable use of the marine ecosystems and their services (Guerry et al. 2012; Slootweg 2016). A conceptual framework for such integration is established by the ecosystem-based approach (EBA) for the management and planning of human activities endorsed by the Convention of Biological Diversity (CBD) within the operational guidance and 12 principles (known as the Malawi principles) on the application of the ecosystem approach (SCBD 2004; CBD 2007). The Marine Strategy Framework Directive (Directive 2008/56/

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EC; EC 2008) requires the application of EBA to the management of human activities, recognizing MSP as a measure for ensuring that the collective pressures of such activities are kept within levels compatible with the achievement of good environmental status and enabling the sustainable use of marine goods and services. Coupling of the EBA with MSP processes is recognized as an emerging paradigm in sustainable ocean management (Domínguez-Tejo et al. 2016). This has been also promoted by the Joint HELCOM-VASAB MSP Working Group (acting in the Baltic Sea region), within its 'Guidelines for the implementation of ecosystem-based approach in MSP', where identification of ES is included as one of the key elements for operationalizing of EBA in MSP (HELCOM-VASAB MSP WG 2015).

Implementing EBA in spatial planning and management of marine ecosystems complies with the objectives of the EU Biodiversity Strategy 2020 which, *inter alia*, sets a target to maintain and enhance ecosystems and their services by establishing green infrastructures and restoring at least 15% of degraded ecosystems (EC 2011). Concomitantly, the European Commission together with EU Member States established an initiative under Action 5 of the EU Biodiversity Strategy on Mapping and Assessment of Ecosystems and their Services (MAES). The aim of MAES is to create a knowledge-based system on ecosystems, including their condition and the services they provide. Such knowledge is essential for advancing biodiversity objectives as well as supporting the development and implementation of other EU policies, including water, climate, agriculture, forestry, marine and regional planning (Maes et al. 2014).

Despite the established policy framework for enhancing the use of MAES in marine areas, as well as the generated knowledge pool on the functioning of marine ecosystems, practical experience in the mapping of marine ES as well as integration of this information in MSP is still limited (Domínguez-Tejo et al. 2016; Beaumont et al. 2017; Drakou et al. 2017). The main challenges that hinder this process are related to: (i) the three-dimensional nature of marine ecosystems and related ES as well as their dynamics in time and space; (ii) limited data availability and accuracy on the distribution of habitats; (iii) insufficient understanding of the ecological functions and processes behind many ES or difficulties to quantify them; (iv) defining the link between bio-physical features of ecosystem and cultural ES such as recreational, educational or aesthetic value, which are assessed based on human experience and perception; and (v) sensitivity of data on some ES with high commercial value (Drakou et al. 2017). This leads to a high level of uncertainty in marine ES mapping and assessment, thus making questionable the applicability of the results in policy- and decision-making.

Implementation of the EBA, including identification and mapping of ES, is a topical issue in all countries around the Baltic Sea. These countries are at different stages of MSP. In fact, approved maritime spatial plans exist only in Germany (BSH 2016) and Lithuania (Lietuvos Respublikos aplinkos ministerija 2017). However, approved plans do not yet include ES assessment. Implementation of the EBA, including the MAES and the SEA for proposed spatial solutions of sea uses, was set as task for the development of the Maritime Spatial Plan for Latvian marine waters (subsequently referred to as – the Plan). This was the first attempt in the Baltic Sea region to apply the MAES in an official MSP process at the national level. This paper presents the Latvian approach, namely the application of MAES in spatial planning of marine areas, and discusses its main challenges.

2. Characterization of the Latvian MSP process

The development of the Plan was carried out in 2015–2016 under the supervision of the Ministry of the Environmental Protection and Regional Development of Latvia according to national legislation (Ministru kabinets 2012). The Baltic Environmental Forum – Latvia coordinated the elaboration of a draft Plan with strong involvement of marine researchers, experts and stakeholders representing relevant sectors and interests (HELCOM-VASAB MSP WG 2017). Parallel to the development of the Plan, a SEA of the draft Plan was undertaken according to Directive 2001/42/EC (EC 2001).

The following objectives were defined for the integration of MAES in the Latvian MSP process:

- to map areas important for the provisioning ES in the Latvian marine waters;
- to apply MAES results in the SEA of the Latvian Maritime Spatial Plan by assessing possible impacts of different sea use scenarios and proposed spatial solutions of the Plan on marine ecosystem and related services; and
- to raise stakeholder awareness concerning the importance of ecosystems in the provision of various societal benefits in Latvia.

The results of MAES contributed to different stages and outputs of the Latvian MSP, including stocktaking of the current status of marine conditions, assessment of scenarios and proposed optimal solutions and their impacts on provisioning environmental ES (Figure 1). The subsequent section presents in detail the methodological approach that was followed in this study.

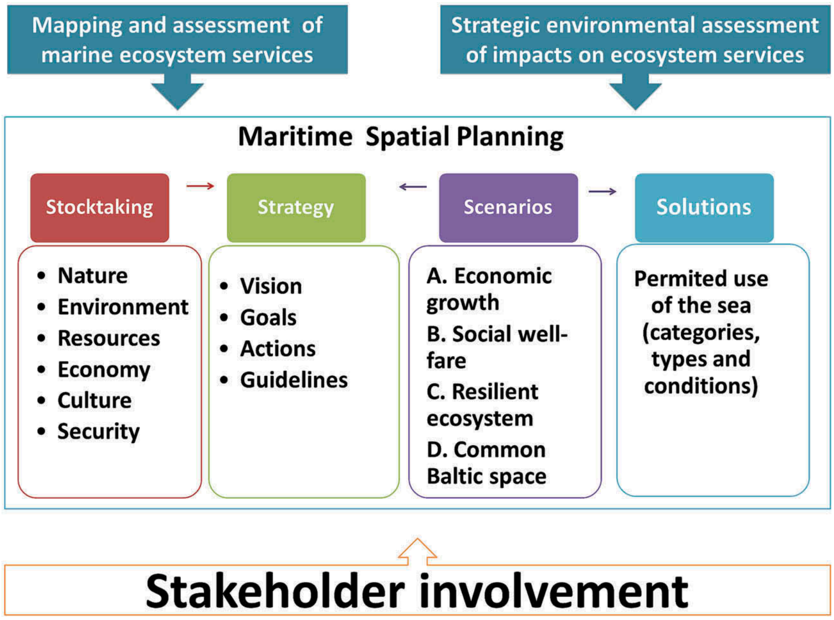

Figure 1. Framework of the Latvian MSP process and links to ES.

3. Methods

3.1. Study area

The study area (Figure 2) includes all marine waters under the jurisdiction of Latvia including internal marine waters, territorial waters and the exclusive economic zone (EEZ) as delineated by the Maritime Administration of Latvia (MALHS 2015). Accordingly, the study area covers about 7% of the Baltic Sea area – 28,518 km^2 of which 10,861 km^2 are territorial waters. Based on existing natural conditions, marine waters are divided into two sub-regions – the

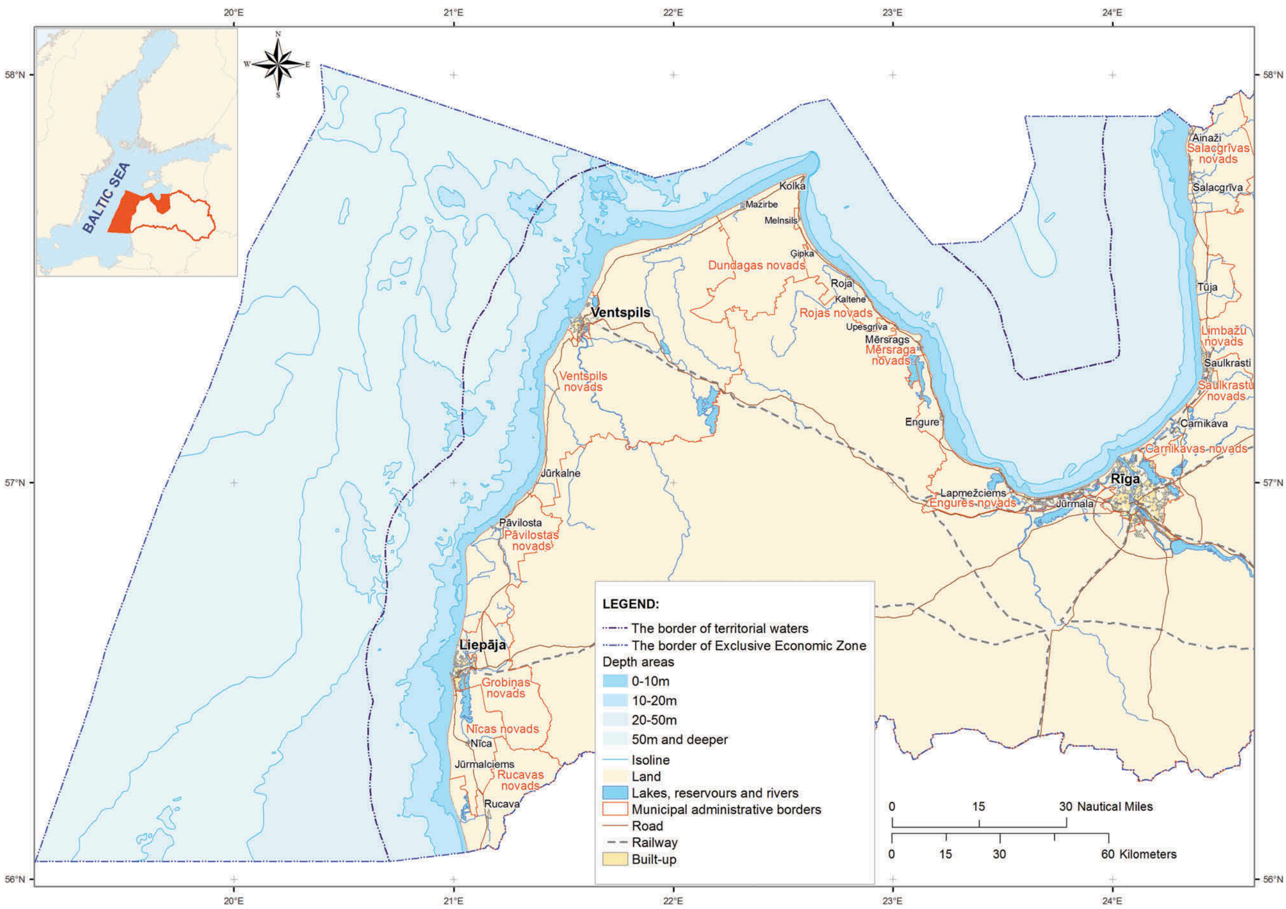

Figure 2. Study area including internal marine waters, territorial waters and EEZ of Latvia.

Gulf of Riga and the Baltic Proper. According to national legislation, marine waters are also subdivided for the purposes of managing fishing activities and fish resources – coastal waters (to a depth of 20 m) and open marine waters (deeper than 20 m) (Ministru kabinets 2007).

3.2. Identification and mapping marine ecosystems

The marine ecosystem consists of two main interconnected sub-systems – pelagic and benthic (Olenin and Ducrotoy 2006). Their structure is formed by the abiotic environment (e.g. sea bottom substrate, depth, differences in the light intensity within the water column), as well as the biotic or living environment (e.g. populations of plankton, benthos, fish, birds and marine mammals). For the purposes of MSP and ES assessment, ecosystems of Latvian marine waters were identified and mapped using the HELCOM Underwater Biotope and Habitat (HELCOM HUB) classification system (HELCOM 2013a). The HELCOM HUB classification describes structures up to six levels for benthic habitats and four levels for pelagic habitats. Level 1 defines the region for which the habitats are classified – the Baltic. The regional split was introduced by HELCOM aiming at the transferability of the system to other marine regions in Europe and compatibility with the European Nature Information System (EUNIS) (Schiele et al. 2014). Level 2 splits habitats into the main vertical sub-systems – benthic (associated with the sea bottom) and pelagic (associated with the water column) – and further sub-divides the vertical zone based on availability of light – photic and aphotic zones. Level 3 applies different environmental factors to classify pelagic (delineated by halocline) or benthic habitats (associated with substrate). Level 4 uses community structure as a split factor for benthic habitats and availability of oxygen for pelagic habitats. Level 5 divides benthic habitats according to typical communities, and finally level 6 according to dominant species groups. All Latvian marine waters were classified as HELCOM HUB benthic habitats based on a coastal survey and monitoring data as well as a sea bottom sediment map (MoEPRD 2016). The latter was specifically prepared using existing geological survey data during the MSP stocktaking exercise. Habitats were delineated at levels 3–5 depending on the availability of field data. In total 26 benthic habitat types were identified and mapped for Latvian marine waters.

Benthic habitat types were used mainly to map and assess regulating services (see next section) while other spatial units (grid network) were used to assess provisioning and cultural services. Detailed mapping of pelagic habitats was not feasible in the frame of the Latvian MSP due to a lack of information and knowledge on spatial patterns (VARAM 2016). Coastal waters were considered as a single ecosystem (or cultural space) when assessing cultural ecosystem services (CES). Specific habitats or ecosystems have seldom been assessed as suppliers of CES (Martin et al. 2016).

3.3. Selection of relevant ES and indicators for assessment

The Common International Classification of Ecosystem Services (CICES, version 4.3; Haines-Young and Potschin 2013) was used to map and assess the supply of marine ES in Latvia. CICES was developed as a framework to structure the ES concept and assist in the exchange of information about ES across regions and different countries (Haines-Young and Potschin 2013). Meanwhile CICES has been widely applied in studies and assessments at different scales including several pilot studies at the pan-European level (Maes et al. 2014). The hierarchical structure up to class level (Potschin and Haines-Young 2016) was applied to identify relevant ES for marine waters.

The choice of ES to be included in the assessment was influenced by data availability as well as the level of knowledge of local experts on processes in marine ecosystems underlying the ES supply. In accordance with CICES, the assessment included:

- two provisioning services (the only service actually supplied – 'wild animals and their outputs' and the potential stocks of 'wild plants, algae and their outputs');
- four regulating and maintenance services ('bio-remediation by micro-organisms, algae, plants, and animals', 'filtration by animals', 'maintaining of nursery population' and 'global climate regulation'); and
- one for cultural services, combining experiential and physical use of land-/seascapes (Table 1).

The choice of relevant indicators for regulating services was based on a review of literature (Hattam et al. 2015) and local expert knowledge, while the indicators for provisioning and cultural services were determined by the availability of data sets. In the context of the ES framework, indicators can characterize different aspects of the ES delivery: (1) a certain potential to supply services based on their functioning (stocks) or (2) actual flow of ES (real supply) which is determined by demand by society (Burkhard et al. 2014; Maes et al. 2016). Most ES studies having a spatial dimension focus on ES supply estimating the hypothetical maximum yield of selected ES (Burkhard et al. 2012). ES indicators

Table 1. ES and indicators used in the assessment of marine ecosystem services.

Section	Division	Group	Class	Indicator
Provisioning	Nutrition	Biomass	Wild plants, algae and their outputs	Area covered by red algae *Furcellaria lumbricalis*
			Wild animals and their outputs	Total catch of commercially important fish species
Regulating and maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants and animals	Area covered by benthic habitats providing this service
			Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants and animals.	
	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Maintaining nursery populations and habitats	
		Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	
Cultural	Physical and intellectual interactions with biota, ecosystems and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	Potential of marine tourism and leisure at the coast
			Physical use of land-/seascapes in different environmental settings	

should be understandable to stakeholders as they are a tool for communication. The indicators should be responsive to changes in the environment and related human activities (Layke et al. 2012; EEA 2014). During the assessment, it was necessary to ensure that the selection of indicators was flexible and consistent across different scales and over time. Consistency in the collection and treatment of statistics and monitoring data ensured comparability between areas. As diverse sets of indicators were available, those most relevant for MAES were selected. Information and data availability was another important criterion for the selection of ES indicators as has been recognized previously in other studies (van Oudenhoven et al. 2012; Kandziora et al. 2013; Maes et al. 2016).

3.4. Assessment of marine ES

Methods for assessment of the selected seven ES varied depending on the type of ES, knowledge and available data. Nevertheless, the same spatial units, a grid network of 3 km × 2.8 km or 0.05° longitude × 0.025° latitude, were applied to ensure coherence in visualization of all ES assessment schemes and assessment results.

A simple qualitative assessment using a binary scale (yes/no) was used for the assessment of regulating and maintenance services. A matrix was created to evaluate capacities of marine benthic ecosystems to provide ES. This method was used due to limited quantitative information and expertise on marine ecosystems, including a lack of direct measurements on the supply of ES. A small expert group composed of key marine biologists in Latvia was established to assess the potential supply of ES by habitat type. Assessment results were compiled on ES maps generated in ArcGIS 10.4 software. This approach has been widely tested and applied previously (Maes et al. 2012; Englund et al. 2017).

Red algae *Furcellaria lumbricalis* is one of the common perennial macroalgae species in Latvian coastal waters as well in the Baltic Sea. Red algae have gel-forming abilities that are relevant to the food industry (Tuvikene et al. 2010). A few countries around the Baltic Sea, for example, Denmark and Estonia, are exploiting the species for commercial purpose. In Latvia, several pilot projects have been implemented; however, industrial scale production is expected in the future. Provisioning services – algae and their outputs – were assessed using a tiered approach (Maes et al. 2014). Tier 1 included the identification of benthic habitats that are related to the distribution of key species (e.g. *F. lumbricalis*) based on expert judgement (i.e. habitat type suitable for growth of the species). Tier 2 included data from field surveys on the coverage of red algae within defined spatial units. The assessment results were presented on a scale of 1–3, where 1 refers to habitats suitable for the species (based on expert knowledge), but where none have been observed so far; 2 – low occurrence observed; 3 – high occurrence observed. Low occurrence means that the coverage of red algae is less than 30% of the monitored site, whereas high occurrence means that the coverage of red algae is above 30%.

Data on fish landings of four commercial species (sprat, herring, cod and flounder) were used as a proxy indicator to assess the flow of the provisioning service – fish for food. Data from fishery logbooks of Latvian fishermen were processed with R Statistical Software to estimate the total value of fish landings in a grid cell per species in the period 2004–2013. Values of the cells were visualized on a scale of 1–5. Pelagic fish (Baltic herring and sprat) dominate catch in terms of the quantity of total landing in Latvian waters (close to 90%). Therefore, the spatial distribution of the fish provisioning ES was determined based on pelagic rather than benthic species.

Assessment of cultural services was carried out with regard to physical and experiential interaction. An indicator of marine tourism and leisure opportunities along the coast was computed based on expert judgement and empirical data from 2015. The indicator combined several criteria: (i) number of visitors; (ii) suitability of the area (or best place) for a particular tourism or leisure activity (e.g. angling, bird watching, kiteboarding, etc.); (iii) accessibility – presence of parking lots and public access roads near the coast; and (iv) data on settlement pattern and population size. Each criterion was scored on a scale of 1–3. The scores of the criteria were summed for the ES assessment on a scale of 1–5, where 1 means very low suitability for tourism and leisure activities and 5 means very high suitability.

3.5. Assessment of impacts of spatial sea use scenarios and MSP solutions on ES

During the MSP process four distinct scenarios (alternatives) were developed, evaluated and optimum spatial solutions elaborated ([MoEPRD 2016). The scenarios were formulated to support planners in outlining a long-term vision, objectives and priorities for spatial sea use as well as to assess possible effects of each scenario. The scenarios approach was a particularly practical method to facilitate discussions with stakeholders regarding respective strengths, weaknesses, opportunities and threats. Identification, description and evaluation of alternatives is also a mandatory requirement of SEA when a policy document is assessed with regard to significant environmental effects on biodiversity, fauna, water, climatic factors, material assets, cultural heritage and landscape (EC 2001). In the Latvian MSP process, scenarios (alternatives) were assessed against multiple criteria: (1) economic, social, environmental and climate change and (2) policy relevance on a relative scale of −2 to +2 (−2: significant adverse effects; −1: slight negative effect; 0: no effect; +1: slight positive effect; +2: substantial positive effect). Spatially, the scenarios were assessed against different components of marine ecosystems (benthic habitats, birds, fish, marine mammals). Expert judgement (hydrobiologists, ornithologists, ichthyologists) was used to assign impact values to each type of sea use and respective ecosystem component and related services. The results of MAES were overlaid on scenarios and problem issues and areas identified. Based on the results of the impact assessment and discussions with stakeholders, optimum spatial solutions were proposed as part of an iterative assessment process. Subsequently, the proposed MSP solutions were reassessed against impacts on marine ecosystems and services using the same multiple criteria method as for scenarios.

4. Results

4.1. Assessment of marine ES

A set of the multiple ES maps was created representing the diversity of provisioning, regulating and cultural ES. Composite maps have been included herein for illustration purposes – ES assessment results and sea uses having significant impacts on ecosystems and their services (Figure 3–6).

The results of MAES demonstrate distinct spatial patterns in the distribution of ES in Latvian marine waters (Figure 5). The deeper part of the Baltic Sea having aphotic benthic habitats on muddy sediments has a higher number of regulating and maintenance services. According to local expert judgement on ES supply by benthic habitats, these deeper open sea areas provide an eutrophication control function through denitrification and the storage of nutrients and control of other pollutants. They also act as a sink for carbon. Assessment results show that coastal areas (photic benthic habitats) contribute to the reduction of eutrophication as soft sandy, hard rock and mixed bottom habitats with associated macrofauna (mussels) that filter nutrients (Petersen et al. 2014). Benthic coastal habitats also maintain nursery populations of fish. These services are provided by reef habitats 'Baltic photic rock and boulders characterized by macroscopic epi-benthic biotic structures' (types AA.A1 and AA.A2, HELCOM 2013a). These habitats are highly important for almost all commercial fish species, especially Baltic herring (Šaškov et al. 2014).

Mapping and assessment results of provisioning services – algae and their outputs (Figure 3) – reveal the importance of coastal areas, in particular coastal

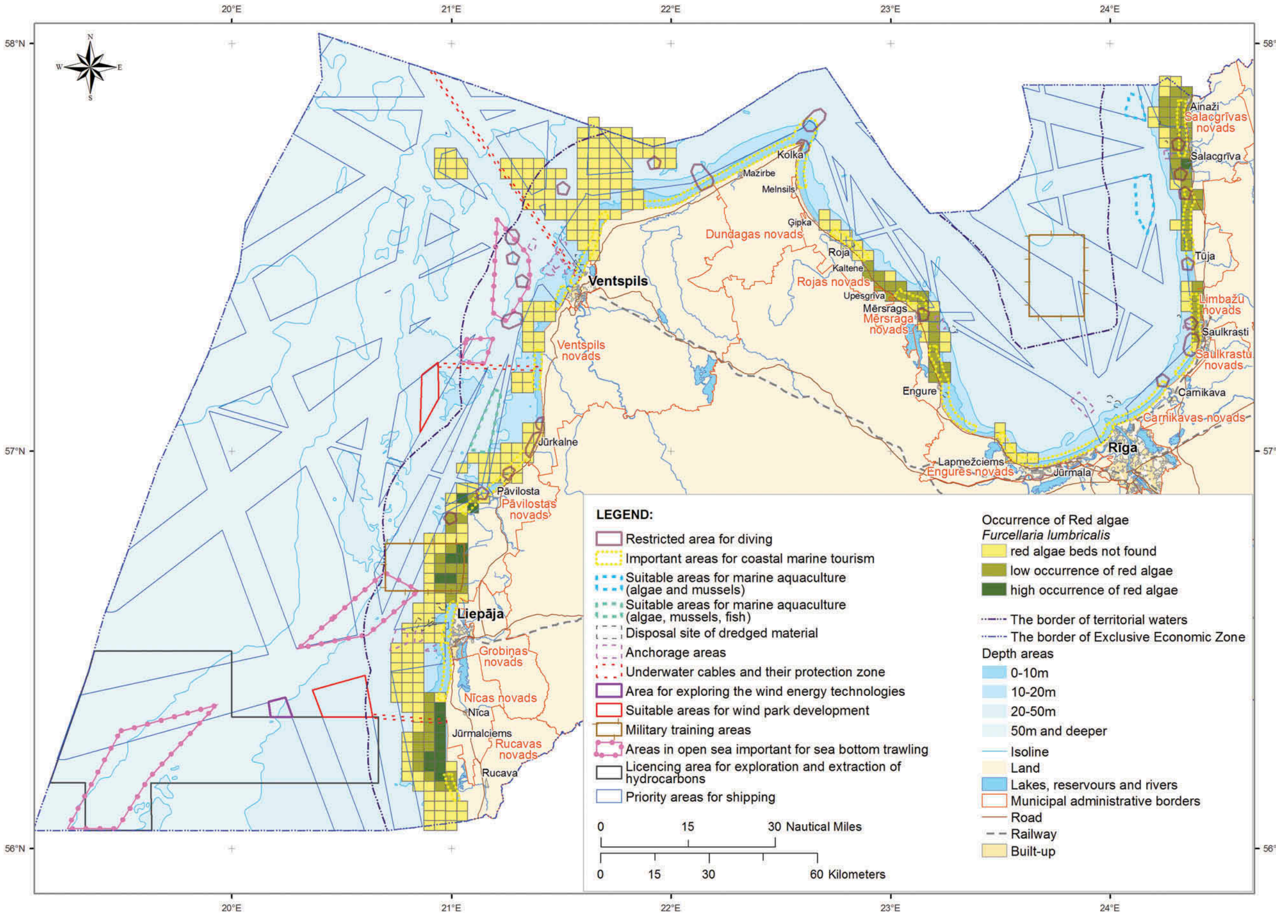

Figure 3. Impacts of spatial solutions on the provisioning service – algae and their outputs. ES indicator: area covered by red algae *Furcellaria lumbricalis*.

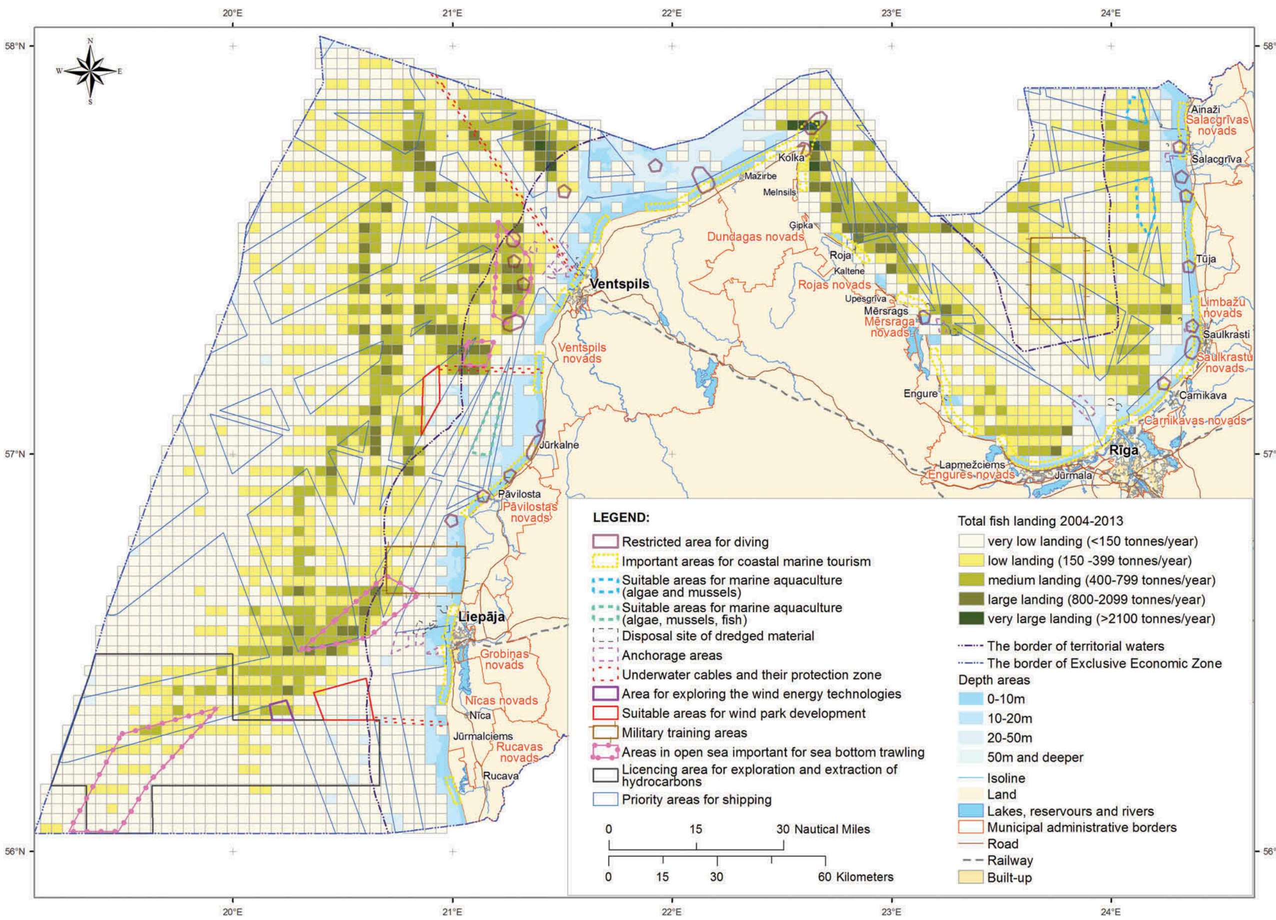

Figure 4. Impacts of spatial solutions on the provisioning service – fish for food. ES indicator: total landing of commercially important fish species (excluding coastal fishery).

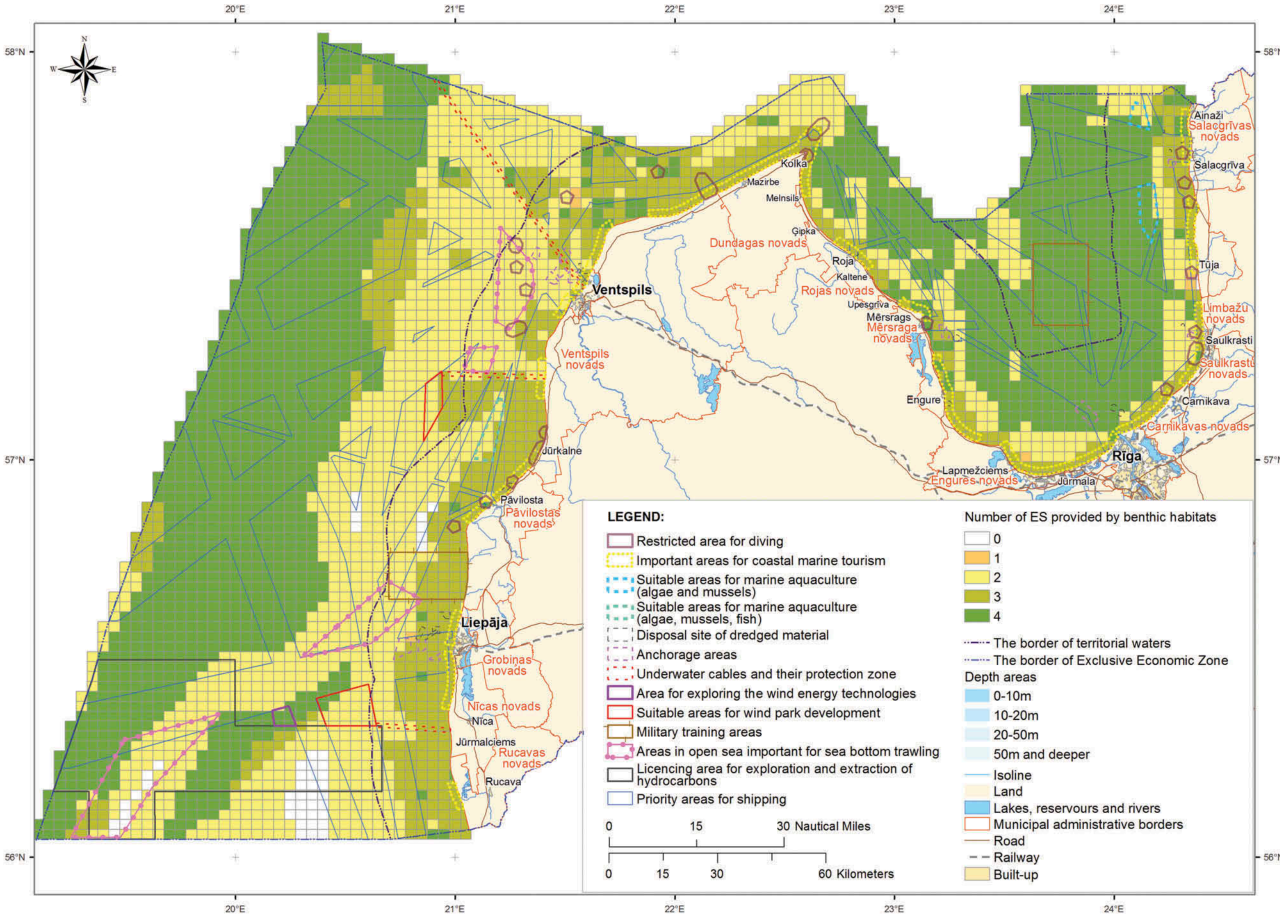

Figure 5. Impacts of spatial solutions on regulating services provided by benthic habitats. ES indicator: number of regulating and maintenance services.

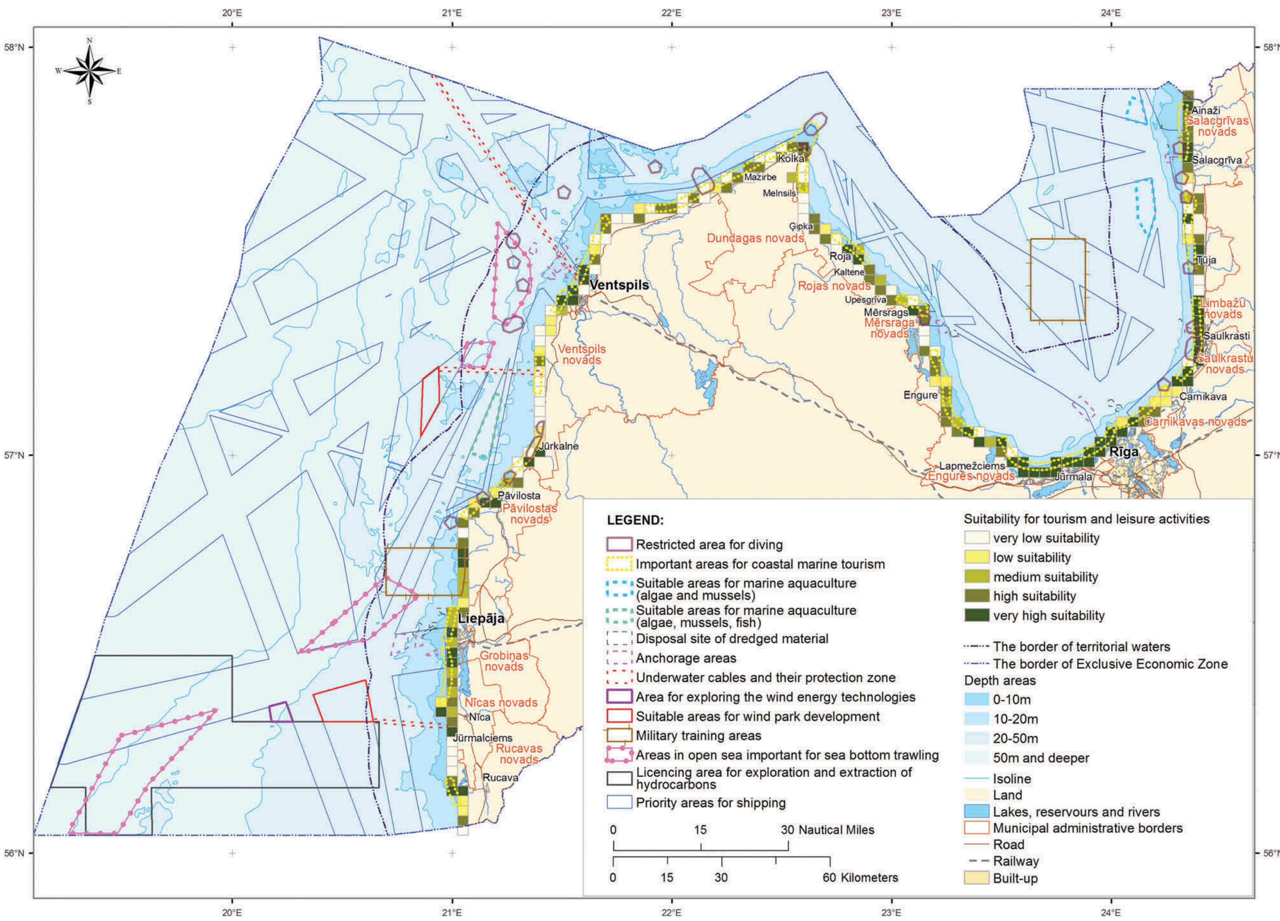

Figure 6. Cultural services – physical and experiential interaction. ES indicator: marine tourism and leisure possibilities at the coast.

habitats. The highest coverage of red algae is observed on reef habitats in the coastal waters of the southwest part of Latvia.

Fish for food is the most common good delivered by marine ecosystems. This provisioning service has been measured and assessed quantitatively as statistics are readily available. Figure 4 shows the spatial distribution of the total landing of commercially important fish species in the open Baltic Sea during the period 2004–2013. Baltic herring and sprat, representing pelagic species, are the dominant landing in Latvia. Baltic herring is the typical species in the Gulf of Riga, whereas sprat in the Baltic Proper. Both species are caught predominantly by trawling vessels. While the coastal or deep water areas are more significant in relation to other types of ES, fishing of pelagic species is more significant offshore.

Latvia has a 500-km coastline. Like elsewhere, the coastal area is the most popular tourism destination and provides space for recreational and leisure activities during the summer season (Veidemane 2011). The flow of cultural ES along the Latvian coastal area varies depending on ecosystem structures and functions (sandy beaches, cliffs, coastal meadows, etc.) and accessibility to particular areas in order to benefit from ES. Infrastructure (roads, parking lots, piers, observation towers, etc.) is a key pre-condition for the provision of this ES as people must be able to reach recreation sites (Paracchini et al. 2014). About 35% of Latvian coastal areas, where public infrastructure is not available, scored low (1–2) for this ES. Spatially there is also a difference between the values along the Gulf of Riga and the open Baltic Sea. The latter scored lower on suitability for marine tourism and leisure (Figure 6). The highest scoring (5) areas were those with a large number of visitors, mainly in the vicinity of large cities and towns with good public access. Areas providing specific marine tourism and leisure activities (scuba-diving, bird watching, angling, kiteboarding, sea kayaking) related to unique features of the marine environment also scored high (4). These sites are typically located closer to smaller settlements.

4.2. Application of MAES results in SEA and defining optimum spatial solutions for sea use

SEA is one of the legally established tools in EU Member States for integrating environmental considerations into development planning documents that are likely to have significant effects on the environment in Member States (EC 2001). Internalization of the ES concept in spatial planning processes through SEA is particularly feasible, however, not so widely applied – and this includes MSP (Geneletti 2011; Slootweg 2016). The ES approach enriches the perspective of the SEA as it covers all relevant ecosystems, cultural aspects as well as economic considerations. The relevant results in relation to impacts on ES are presented below. They illustrate how the results of MAES have been integrated into the environmental impact assessment and the MSP process.

4.2.1. Assessment of impacts on provisioning marine ES

Exploitation of red algae *F. lumbricalis* by the food industry is very unlikely as the richest areas are designated as marine-protected areas in order to protect reefs which are habitats of EU importance (HELCOM 2013b). Moreover, these areas are also important for other sea uses such as fishing and tourism. Although new information and knowledge were generated on the availability of potential provisioning ES that could serve as new resources for economic innovation, Latvian planners and stakeholders were of the opinion that the Plan should not promote the direct use of red algae during the current cycle of MSP.

As described above, fish for food is the only provisioning ES that is presently directly assessable in a quantitative way. Considering the exclusionary conditions existing between fisheries and the majority of new sea uses (Berkenhagen et al. 2010) identification of areas with lowest environmental impact on fish resources was essential in the Latvian MSP process and corresponding SEA. Figure 4 shows that two areas identified as suitable for wind park and aquaculture development in Latvian marine waters overlap with areas having very low or low fish landing volumes during 2004–2013. Moreover, these potential development areas are areas where mainly pelagic trawling takes place. Benthic fish (flounder, cod) are fished by bottom trawling and therefore are more bound to certain areas compared to pelagic fishing. To maintain benthic fishing activity, a number of areas were identified and classified as key priorities for protection in the Latvian Plan. In areas important for the provisioning of fish resources, new stationary construction (e.g. off-shore wind turbines) is not planned to avoid negative impacts to living conditions of benthic species.

4.2.2. Assessment of impacts of regulating marine ES

Proposed spatial solutions for new sea uses – off-shore energy production and aquaculture – do not spatially overlap with those areas providing the highest number of regulating and maintenance ES (Figure 5). Two areas identified as suitable for off-shore wind energy production would have the effect of reducing denitrification services which are important for maintaining nutrient balances and thus influence eutrophication which is the main environmental issue in the Baltic Sea (HELCOM 2009). However, the size of the areas (c.a. 207 km^2) is relatively small, representing an insignificant share (less than 1%) of the total Latvian marine space.

Areas that are already licenced for exploration and extraction of hydrocarbons occupy a larger share of space and assessed ES. Decisions on licencing these areas were taken before the launch of the MSP process and thus were not rescinded despite the potential significant impact on identified ES. The current legislation does not allow issued licences to be terminated; therefore, the SEA could only recommend that mitigating measures be considered during the planning phase of any upcoming development proposal and related environmental impact assessment.

Two areas suitable for aquaculture – mussel and algae farming – were identified in the Gulf of Riga. MAES results show that these areas are locations where benthic habitats support the reduction of eutrophication. As farmed mussels and algae perform in a similar way with respect to the reduction of eutrophication, the assessment concluded that aquaculture will provide the same services as existing natural benthic habitats.

4.2.3. Assessment of impacts of cultural services

CES – physical and experiential interaction – were assessed within the MSP process (Figure 6). Areas assessed high and very high were identified as priority areas for marine tourism development in the Plan. This means that future development of public infrastructure will be targeted to these areas having potentially higher social benefits.

Although cultural services – intellectual and representative interactions – were not explicitly mapped and assessed, the MSP process and corresponding SEA considered recent research results on the aesthetic value of sea/landscapes (Veidemane and Nikodemus 2015). This research focused on the importance of visual changes in coastal landscapes for tourists, beach users as well as local residents in Latvia. Research results revealed that the distance to an offshore wind park can have a significant impact on tourism and recreation. Furthermore, stakeholder consultations organized in the ambit of the MSP process and corresponding SEA confirmed that coastal residents oppose the siting of any wind park at a visible distance. Therefore, a distance of at least 20 km from the coast was among the criteria for identifying suitable areas for wind park development in the Plan.

5. Discussion and conclusions

Although during the past decade MAES and the application of the EBA and SEA in MSP have become a relevant research issue and are high on the marine policy agenda, the integration of MAES into MSP still can be regarded as a novel approach facing managerial, methodological as well as conceptual challenges (Lester et al. 2013; Börger et al. 2014; Domínguez-Tejo et al. 2016; Drakou et al. 2017). For the Latvian case these are described below.

Managerial challenges: One of the major limitations for the proper application of MAES in MSP processes is the rather short time frame allocated for the development of maritime spatial plans (Börger et al. 2014). This was also the case with respect to the Latvian MSP process, which was implemented in a 16-month period, including stocktaking, consultations with sectors, scenario building, formulation of proposed MSP solutions, assessing impacts to the environment and public hearings. The short time frame was even more challenging due to data scarcity on marine ecosystem structure and functions. To overcome this challenge the best available data and expert knowledge were applied. Even so, this included the time demanding activity of developing a sea bottom sediment map used as the basis for the benthic habitat map. Distribution of benthic habitats was in some cases used as a proxy for ES mapping. However, a proper assessment of the economic and social value of ES, which would require extensive social surveys, was not feasible in the given time frame and budget limitations. Less time-consuming and costly methods, such as benefit transfer, would not be appropriate in this case either due to a lack of studies from similar marine sites with comparable ecological and socio-economic conditions (Börger et al. 2014).

Methodological challenges: One of the major methodological challenges was the multi-dimensional character of the marine environment (including the sea bottom, the water column above it, the water surface as well as the temporal dimension) and related difficulties to define appropriate spatial assessment units to which various marine ES can be attributed (Drakou et al. 2017). Similar to terrestrial ecosystems where land use/land cover data layers are used for input or proxy for the assessment of ES, marine habitat maps can be applied to the mapping and assessment of marine ES (Guerry et al. 2012). This approach was also applied in the Latvian MSP process, where benthic habitat maps were used as a proxy for mapping the distribution of regulation and maintenance services as well as one provisioning service – algae and their outputs. The vulnerability concept could enhance mapping and assessing a habitat's ability to deliver ES. Vulnerability is calculated as a function of exposure (nature and degree to which an ecosystem is exposed to the change), sensitivity and adaptive capacity of the habitat (Cabral et al. 2015).

However, not all marine and coastal ES depend on the distribution of benthic habitats. For example, the largest share of commercial fish landing in Latvian marine waters (e.g. sprat and herring) is related to pelagic habitats, and thus requires a different mapping method. Furthermore, the distribution of fish populations is influenced even more by temporal factors – e.g. seasonality, yearly fluctuations of physiochemical water conditions including nutrients, as well as climate change (Olsson et al. 2015). In relation to the MSP process in Latvia, the mapping of ES provided by pelagic habitats was undertaken by aggregating a 10-year data set on the total landing of fish. However, more recent fishery data show that the chosen 10-year period might be insufficient to represent the spatial and temporal variability of the distribution of pelagic fish populations.

Conceptual challenges: The capacity of an ecosystem to supply ES depends on the state of its structure, processes and functions determined by interactions with socio-economic systems (Maes et al. 2013). In order to support the MSP process, the ES assessment should be able to evaluate how the anticipated changes in marine ecosystem structure and functions would affect the flows of services (i.e. to apply the so-called ecological production function approach) (Guerry et al. 2012). However, as noted by Rivero and Villasante (2016), the quantitative relationship between the structure, processes, functions and services of the marine ecosystem is still poorly understood, as are the cumulative effects of various human uses on the marine ecosystem and a variety of ES. Consequently, at this stage it is difficult to carry out a proper trade-off analysis of the impacts of different scenarios and solutions for sea use for the provision of ES and human well-being. Similarly, communicating MAES results as a justification for preventing human uses with adverse impacts on marine ecosystems and services is also problematic (Albert et al. 2017).

Uncertainty of MAES results: A lack of direct monitoring data, low accuracy of spatial data sets that are used as proxies in the ES assessment, as well as insufficient understanding of natural processes leads to uncertainty in the quantification and mapping of ES (Schulp et al. 2014). This problem was faced when mapping the regulating and maintenance services within the Latvian MSP process. For example, due to a lack of relevant field data, the benthic habitats map and expert knowledge were used to identify the potential distribution of services related to bio-remediation, filtration of nutrients, maintaining of nursery populations and global climate regulation. The precision of the benthic habitat map of Latvian marine waters varies considerably depending on the level of HELCOM HUB classification applied in different zones of the sea. Areas mapped in the coastal zone (up to level 5 of HELCOM HUB classification) are based on biological data from a field survey, whereas the remainder of the area is coarsely mapped (up to level 3) using only bathymetric and substrate data. Furthermore, the specificity of ecological conditions in the Baltic Sea does not allow for the transfer of monitoring data from other marine regions for the assessment of ES supplied by different Baltic habitats. The situation differed regarding mapping of selected provisioning services (total landing of commercial fish and area covered by red algae) as well as cultural services (tourism and leisure opportunities in coastal areas), where data on actual service use were applied.

Thus, the level of detail of available input data as well as limitations of human and time resources dictated the use of a tiered approach (Maes et al. 2014; Grêt-Regamey et al. 2017) to MAES within the Latvian MSP process. As suggested by Grêt-Regamey et al. 2017, the appropriate tier should be defined according to the goal of mapping exercise. The highest possible accuracy in ES mapping (tier 3) would be required in MSP because it is essential not only to gain an overview of the distribution of ES but also to provide appropriate input to SEA and management decisions on the use of marine ecosystems. However, taking into account the limitations of the data and resources, the best available data sets and knowledge were applied, resulting in a tier-1 approach for mapping of regulating and maintenance services, whereas a tier-2 approach was possible in the case of provisioning and cultural services.

Considering that MSP is an adaptive process (Börger et al. 2014), this provides an opportunity to include new MAES findings within the next planning cycle, which would require development of integrated ES modelling approaches and establishing links between ecosystem conditions, processes, human impacts and related ES outputs expressed as economic and social benefits.

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