Baltic Marine Environment Protection Commission

A1.4 Annex 2

Socioeconomic assessment of the Baltic Sea marine ecosystem services for assessing well-being impacts of marine protection and management policies

BLUES

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Socioeconomic assessment of the Baltic Sea marine ecosystem services for assessing well-being impacts of marine protection and management policies

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Introduction

Ecosystem services (ES) are the direct and indirect contributions ecosystems make to human well-being, arising from the interaction of biotic and abiotic processes (Potschin and Haines-Young, 2016b), and they are fundamental to the well-being of humanity. ES are generated by structures and processes of the ecosystem and provide goods, like wild fish and algae to nutrition, assimilation of substances from human activities, like carbon sequestration, and non-material gains from interacting with the ecosystem, like recreation. The ES approach is a common method in environmental policy and management, used to understand and conceptualize interactions between ecosystems and human well-being. This approach can be seen as a way of understanding the complex relationship between nature and society, to support decision and policy making with the aim of ensuring the sustainable use of resources (Martin-Ortega et al., 2015).

Reviews on the state-of-the-art with respect to the ES assessments identify significant gaps for such assessments and their application for policy support. A review by Galparsoro et al. (2022) on operationalisation of the ES approach to support policies, which was conducted in the Maritime Spatial Planning (MSP) context, summarises the main gaps and needs for future work in relation to (i) improvement and adaptation of existing ES frameworks and classifications to the marine realm and (ii) definition of an indicator pool; (iii) methodological and technical developments to support data availability and accessibility; (iv) advances in mapping and modelling methods; (v) improvements in assessment and valuation approaches; (vi) further use of scenario and trade-off analysis; (vii) taking advantage of supporting Information Technologies; (viii) improvements in communication and engagement with stakeholders; and (ix) further work for the integration of ES knowledge into policies and for supporting management and MSP. They conclude that particular focus should be given to the integration of non-monetary and monetary valuation methods to provide socio-economic indicators for the demand of ES that can better explain the benefits to society. They also note that it is essential to reduce uncertainty and to increase the reliability of assessment and valuation of ES to be used in real management plans development. A review by Heckwolff et al. (2021), conducting a systematic review of coastal ES in the Baltic Sea, concludes that there is good quantitative information about how ecosystems generated the service but almost no knowledge of how they translate into socio-economic benefits. They note that research on the Baltic Sea socio-economic benefits does exist, but the link with ecosystems providing the service is mostly missing. To close this knowledge gap, there is also a need for a better analytical framework that is capable of directly linking existing quantitative information about ES generation with human benefit.

The updated HELCOM Baltic Sea Action Plan (HELCOM, 2021) includes actions on integrating the economic and social analyses in HELCOM work strands to allow for assessment of the linkages between the marine environment and human wellbeing (HT15), on further development and application regionally coordinated methods in support of analyses of ES and providing an initial demonstration of how they can be used in policy development (HT18), and on improving the use of results from economic and social analyses in decision-making, including through establishing a set of indicators that describe the economic and social aspects of the marine environment (HT16).

This assessment has been developed as part of HELCOM BLUES project[1] to address the gaps and needs for further development of the ES approach and assessments to support the Baltic Sea policies. The assessment contributes to implementation of the BSAP actions by (i) further development of the sea region policy assessment framework[2] by integrating the ES approach for more explicit linking the marine environment and human well-being and assessing the well-being impacts of policies; (ii) developing a sea region scale approach and assessments for quantitative and monetary estimation of the ES benefits and socioeconomic values and (iii) providing an initial demonstration on how such socioeconomic assessments can be used in policy development. The developed approach aimed in particular to improve the links between the ecosystem (its components, generating the ES) and benefits to humans and to cover diversity of the values, which cannot be reduced to one (monetary) metrics. The work was done in collaboration with HELCOM MetDev project[3] and the ES supply analysis for HOLAS 3, which developed quantitative estimates on the ES supply and benefits, ensuring the links between the marine ecosystem and human well-being.

The given report summarises the results of the ES assessment work done as part of the BLUES project. Figure 1 provides a graphical summary on the main assessment results for the sea region scale (the Baltic Sea). The report is further structured as follows: Sections 1-3 describe the used concepts, the conceptual framework and relevant methodological issues of the assessment, the developed list of the Baltic Sea relevant marine ES and the assessment approach, which is based on using an indicators' approach. Section 4 provides the developed estimates on the ES benefits and socioeconomic values, as well as illustrations on assessments of well-being impacts of policies by applying the ES approach. The report ends with conclusions and recommendations for the future work to further develop the sea region scale ES assessments for the Baltic Sea (Section 5).

[1] "HELCOM Biodiversity, Litter, Underwater noise and Effective regional measures for the Baltic Sea" (HELCOM BLUES). For more information about the project see https://blues.helcom.fi/.

[2] Developed as part of the HELCOM ACTION project and complemented as part of the HELCOM BLUES project.

[3] HELCOM Holistic Assessment Methodology Development Project.

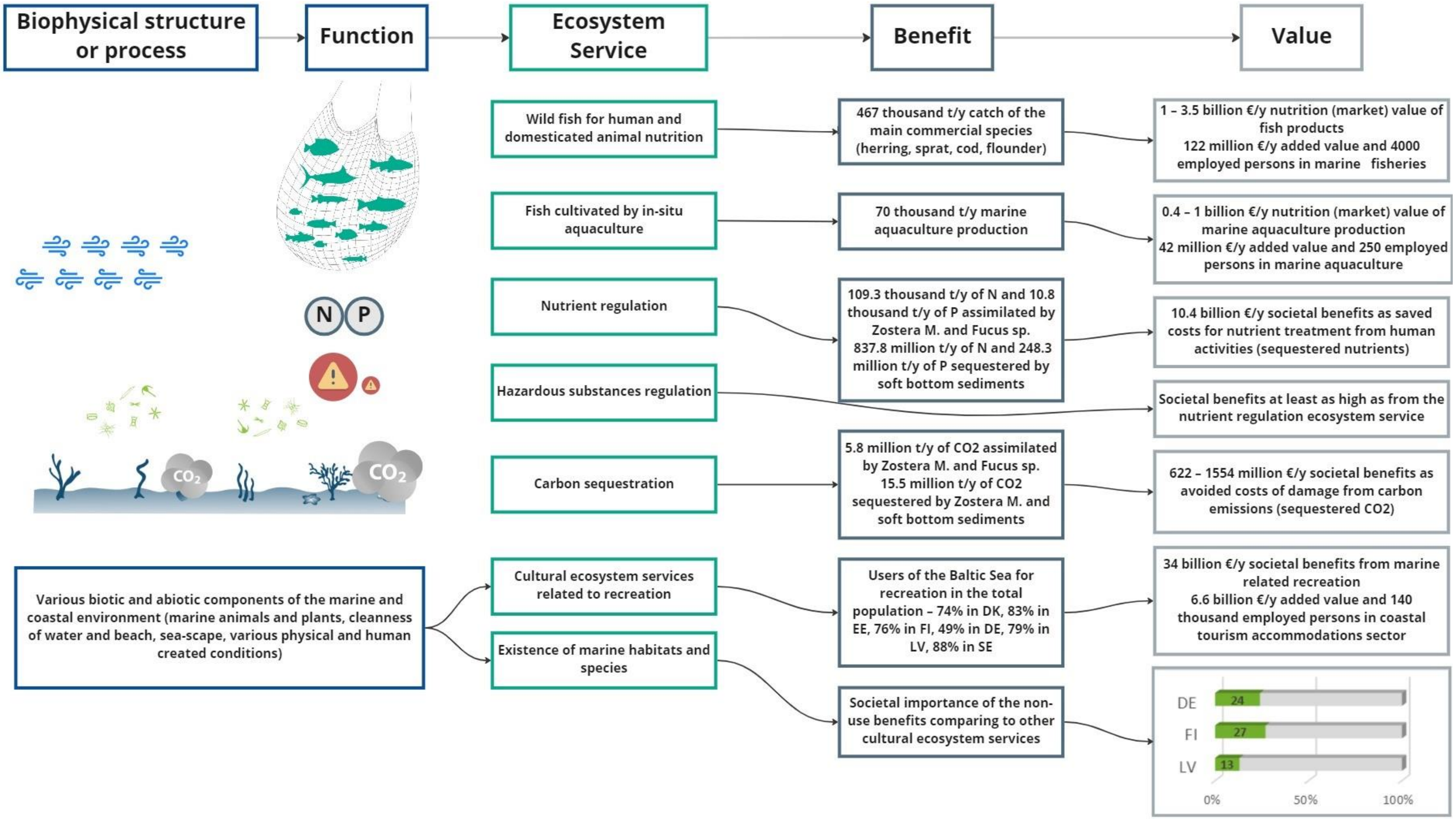


Figure 1. A graphical summary on the main assessment results for the sea region scale (the Baltic Sea). (Source: ES supply analysis for HOLAS 3 and own work.)

1. Concept and definitions

The developed ES assessment builds on the concept of the ES cascade model (Potschin and Haines-Young 2016a), which was developed to explain how the notion of ecosystem services can be used to understand the relationships between people and nature (Potschin & Haines-Young 2016b). The cascade model is an expression of the key components of the ES paradigm, which scrutinise the distinction between what are understood as 'services' and 'benefits', and to examine the particular 'functional' characteristics of ecosystems that give rise to services, as opposed to the more general ecological structures and processes that support them. The cascade model is used as a basis for the CICES classification of the ES (Haines-Young and Potschin, 2018) and is consistent also with MAES (Maes et al., 2013). The ES cascade can be integrated into the DAPSIR[4] framework, since the ES approach aims to be used for assessing well-being impacts of policy measures for protecting and sustainable use of the marine ecosystem (Figure 2).

The CICES classification seeks to classify only final ES. Supporting and intermediate ES are covered by the cascade elements on "Processes" and "Functions" (Haines-Young and Potschin, 2018; Potschin-Young et al., 2017). At the same time, each ecosystem provides a range of ES that make contributions to human well-being in many different ways (Haines-Young and Potschin, 2018). The problem of context dependency makes the classification of final ES difficult. Some of the ES have direct link to the human well-being (e.g. provisioning and cultural ES), while some contribute indirectly via other ES (all maintenance ES). Regulation ES provide both direct and indirect contribution to well-being. This issue has to be addressed when valuing the benefits to avoid double-counting. It is addressed by distinguishing direct and indirect benefits to human well-being. Figure 3 provides an example concerning the ES "nutrient regulation", which provides both direct and indirect benefits.

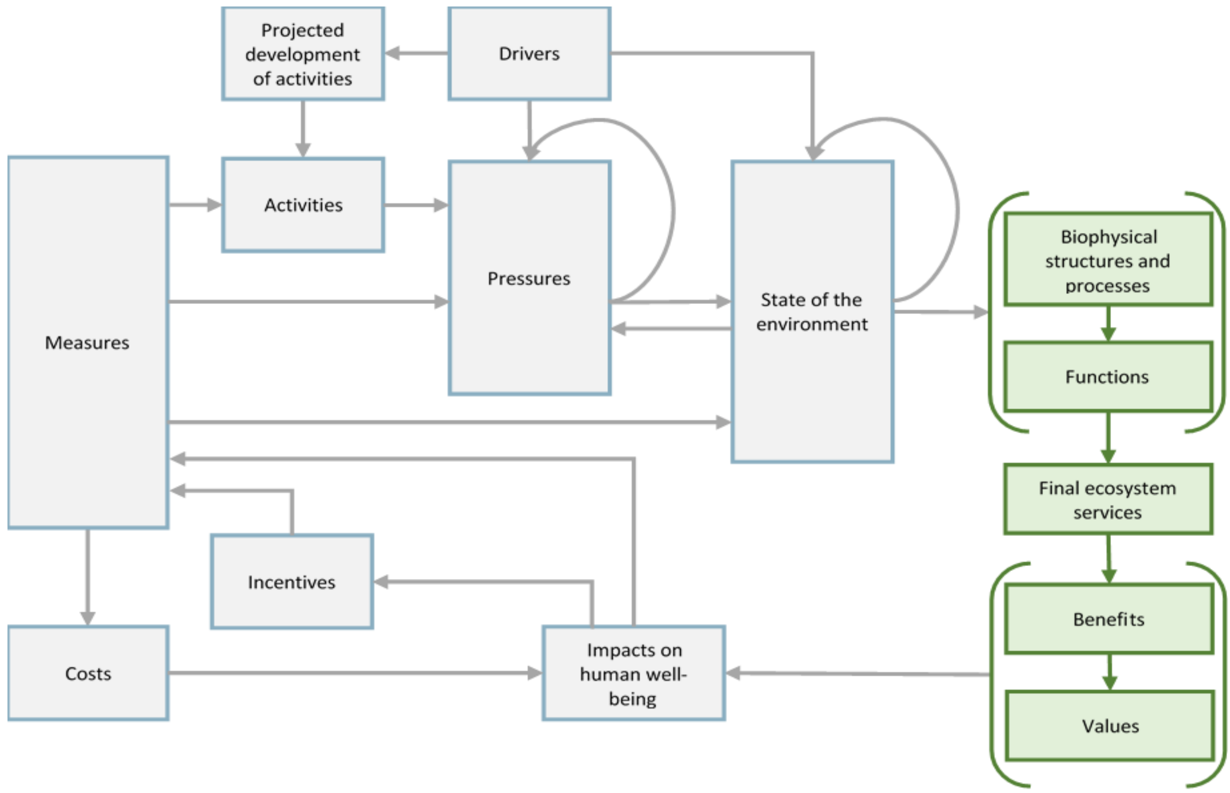


Figure 2. Conceptual framework, based on DAPSIR framework and including the ES cascade model, for assessing well-being impacts of policies for protecting and sustainable use of the marine environment. (Source: Own work). The ecosystem services cascade elements are included according to Potschin and

[4] Drivers, Activities, Pressures, State, Impact, Response (Measures).

Haines-Young (2016a), and the links between DAPSI(W)R(M) and ES cascade elements according to Kandziora et al. (2013). The green colour denotes elements of the ES cascade.

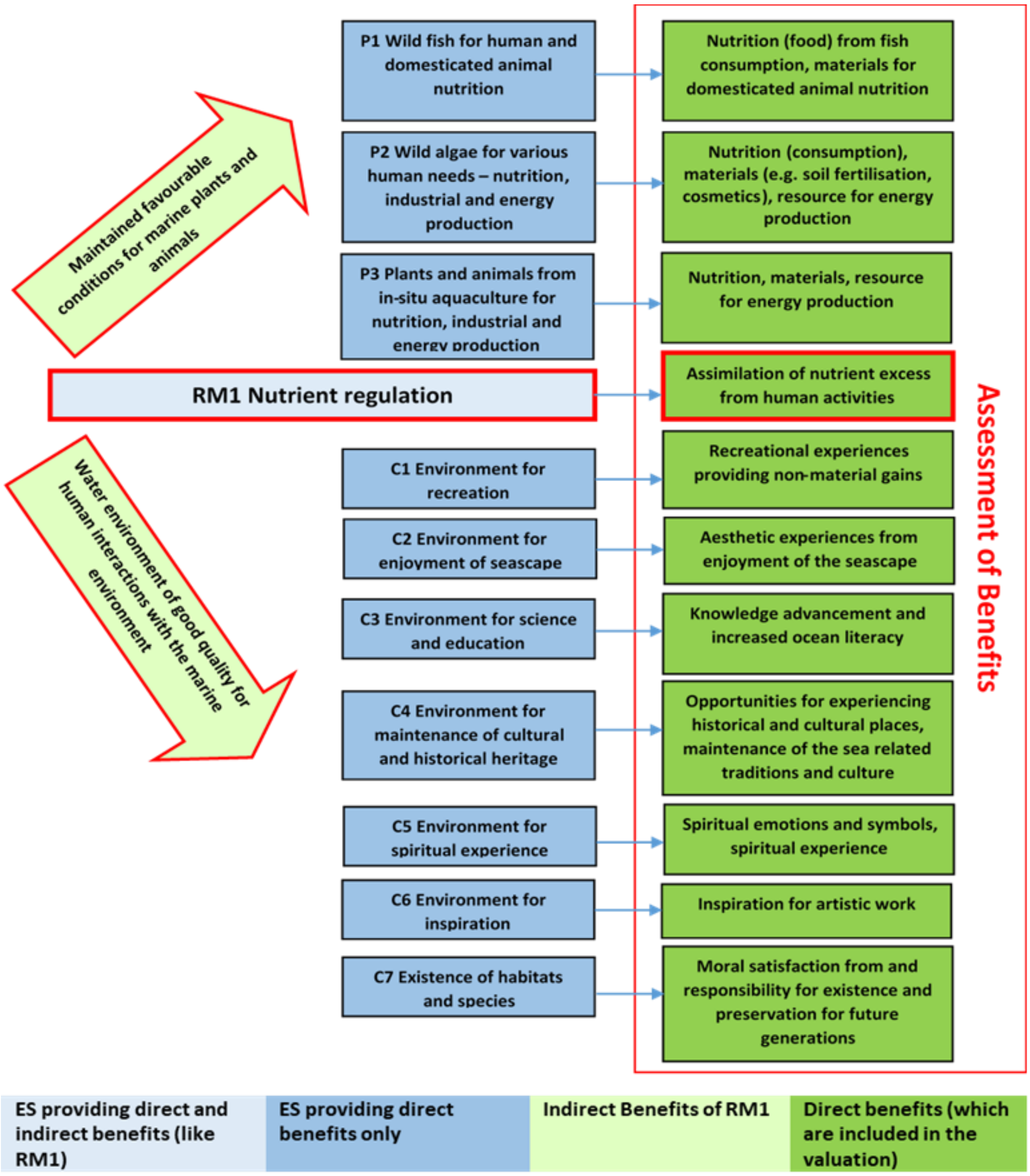


Figure 3. Direct and indirect benefits of the ecosystem service "RM1 Nutrient regulation" and their valuation. (Source: Own work.)

For specifying the ES and corresponding benefits (and values), the elements in the ES cascade are defined as follows (Potschin and Haines-Young 2016b):

Ecosystem services: *"The **contributions** that ecosystems (whether natural or semi-natural) make to human well-being; their fundamental characteristic is that **they retain the link to underlying ecosystem functions, processes and structures**."* This definition corresponds to the concept of final ES used in some classifications.

Benefits: *"The direct and indirect **outputs** from ecosystems **that have been turned into products or experiences** that are **no longer functionally connected to the systems** from which they were derived. Benefits are things that can be valued either in monetary or social terms."* This definition can be thought to incorporate the concept of goods, as both are things that have value to people.

Values: *"The criteria by which people assign/justify importance to/of things. Values can be individual or collective, and can be qualitative or quantitative. The definition recognises that ecosystem services can embrace different types of values that cannot be reduced to one (monetary) type."*

Human well-being: *"Human well-being is that which arises from adequate access to the basic materials for a good life, that are needed to sustain freedom of choice and action, health, good social relations and security. The state of well-being is dependent on the aggregated output of ecosystem benefits, and is thus distinct from individual benefits."*

2. The list of marine ecosystem services

The developed ES list for the socioeconomic assessment (Table 1) is based on the ES classification CICES V5.1, the ES relevant for marine ecosystem (Haines-Young and Potschin, 2018). It has been modified to include only the relevant ES and combine some CICES classes.

Only biotic ES are considered in the current approach, covering all ES groups (provisioning, regulating and cultural ES). The assessment aims to support the marine protection policies (e.g. HELCOM, MSFD, EU Biodiversity Strategy), and primarily the biotic ES are impacted by such policy measures. However, the approach allows inclusion of the abiotic ES also depending on the needs in the future (e.g. Coastal and marine water used as energy source; Mineral substances used for material purposes; Wind energy; Mediation by other chemical or physical means (e.g. via filtration, sequestration, storage or accumulation)).

For each ES corresponding benefits are specified, distinguishing direct and indirect benefits (Table 1). Specifications of ES and benefits are developed, corresponding to the definitions provided in Section 1.

Table 1. The list of ecosystem services and the corresponding benefits. The direct benefits are indicated with black text and the indirect benefits with grey Italic text.

Ecosystem services (name and specification)	Benefits
GROUP: PROVISIONING ECOSYSTEM SERVICES	
P1 Wild fish for human and domesticated animal nutrition Species of wild fish for human consumption as food, e.g. Herring, Sprat, Cod. Species of wild fish for domesticated animal nutrition.	Food (various fish products) for human consumption. Materials (e.g. fish meal) for domesticated animal nutrition.
P2 Wild algae for various human needs – nutrition (human consumption), industrial and energy production Wild algae (e.g. Fucus vesiculosus and Furcellaria lumbricalis) for human consumption as food additives. Wild algae collected on the shore and used for soil fertilization, cosmetics. Wild algae biomass used for the production of biogas and biomethane.	Food (e.g. food additives) for human consumption. Materials for soil fertilisation, cosmetics. Resource for energy production.
P3 Plants and animals cultivated by in-situ aquaculture for nutrition, industrial and energy production Cultivated fish species, mussels and algae grown for nutritional purposes, as a material for various uses and as an energy source	Food, materials, resource for energy production.
P4 Genetic materials from plants and animals [Not elaborated; can potentially be included if relevant for the sea region]	[not elaborated; can be included if relevant]

Ecosystem services (name and specification)	Benefits
GROUP: REGULATION AND MAINTENANCE ECOSYSTEM SERVICES	
RM1 Nutrient regulation Filtration, uptake, use for biomass production of nutrients (nitrogen, phosphorus) by any living organism (bacteria, algae, fungi, invertebrates, vertebrates), leading to mitigation of eutrophication. Includes such processes as nitrogen removal process carried out by bacteria (denitrification); phosphorus burial in marine sediment (nutrient regulation by phosphorus burial); nutrient regulation by nitrogen incorporation in biomass; nutrient regulation by nitrogen assimilation. Note: Sub-divided to facilitate linking to the contributing ecosystem components (distinguishing assimilation, storage and sequestration/burial).	Assimilation of nutrient excess from human activities [Direct benefit] *(Indirect benefits, valued as part of (direct) benefits of other ES:* • *Maintained favourable conditions for marine plants and animals (e.g. oxygen and light conditions) supporting provision of food and materials (linked to Provisioning ES);* • *Water environment of good quality (e.g. with clear water and clean beaches, diverse species populations) for recreation and other human interactions with the marine environment (linked to Cultural ES);* • *Nutrient regulation for other Regulation ES.)*
RM2 Hazardous substances accumulation and transformation Filtration, uptake, biodegradation, biodeposition, bioaccumulation of hazardous substances by any living organism, leading to mitigation of pollution.	Assimilation of hazardous substances from human activities [Direct benefit] *(Indirect benefits, valued as part of (direct) benefits of other ES:* • *Maintained favourable conditions for marine plants and animals supporting provision of food and materials (linked to Provisioning ES);* • *Water environment of good quality (e.g. with safe and clean water and marine organisms) for recreation and other human interactions with the marine environment (linked to Cultural ES).)*
RM3 Carbon sequestration Regulation of atmospheric CO_2 (and other greenhouse gases) by biological fixation in process of photosynthesis (e.g. by macro-algae, phytoplankton), dissolution in the sea water, and sequestration in sediments. Note: Sub-divided to facilitate linking to the contributing ecosystem components (distinguishing assimilation, storage and sequestration/burial).	Climate change mitigation and sustained living conditions due to carbon capture and storage, reducing carbon dioxide and other greenhouse gasses in the atmosphere [Direct benefit] *(Indirect benefits, valued as part of (direct) benefits of other ES:* • *Maintained favourable conditions for marine plants and animals supporting provision of food and materials (linked to Provisioning ES);* • *Maintained favourable conditions for recreation and other human interactions with the marine environment (linked to Cultural ES).)*
RM4 Erosion regulation [Not elaborated; can potentially be included if relevant for the sea region]	[not elaborated; can be included if relevant]

RM5 Pest and disease control [Not elaborated; can potentially be included if relevant for the sea region]	[not elaborated; can be included if relevant]
RM6 Dispersal Dispersal of gametes and larvae contributing to the building and renewal of characteristic habitats.	*No direct benefits.* *(Indirect benefits from the contribution into Provisioning, Cultural and Regulation ES)*
RM7 Maintenance of habitats and nursery populations Maintenance of species characteristic nursery populations and habitats, for example, dense vegetation of perennial macroalgae for successful spawning of Baltic herring.	*No direct benefits.* *(Indirect benefits from the contribution into Provisioning, Cultural and Regulation ES)*
Ecosystem services (name and specification)	**Benefits**
GROUP: CULTURAL ECOSYSTEM SERVICES	
C1 Environment for recreation Environment for recreational activities such as swimming, relaxing on the beach, physical leisure/sport activities, nature observation, angling. [Note: Relate to physical and experiential interactions with natural environment through active or immersive interactions and passive or observational interactions]	Recreational experiences providing such non-material gains as feelings (like de-stress, physical and mental relaxation, and feeling of comfort), health, opportunities for social interaction with other people and other
C2 Environment for enjoyment of seascape Environment for enjoyment of the scenery/sea-scape. [Note: Relate to interactions with natural environment that enable aesthetic experiences]	Aesthetic experiences from enjoyment of the seascape
C3 Environment for science and education Environment and nature values for science and education, e.g. for research stations and programs, nature parks, museums, education programs, excursions, popular-science information in mass media. [Note: Relate to intellectual interactions with natural environment that enable scientific investigation or the creation of traditional ecological knowledge, education and training]	Knowledge advancement and ocean literacy (learning and gaining new information)
C4 Environment for maintenance of cultural and historical heritage Environment for maintaining sea related cultural and historical heritage and traditions. [Note: Relate to intellectual and representative interactions with natural environment that are resonant in terms of culture or heritage]	Opportunities for experiencing sea related historical and cultural places, for maintenance of the sea related traditions and culture
C5 Environment for spiritual experience Environment for spiritual emotions, rituals and symbols. [Note: Relate to spiritual and symbolic interactions with natural environment that have symbolic, sacred or religious meaning]	Spiritual emotions and symbols, which create sense of place/belonging and identity, spiritual experience
C6 Environment for inspiration Environment providing source of inspiration for artistic work.	Inspiration for artistic work, e.g. photography, producing marine inspired design, music, films, literature, paintings

[Note: Relate to other interactions with natural environment for entertainment or representation]	
C7 Existence of habitats and species Preservation for future generations and existence of the habitats and species. [Note: Relate to biotic characteristics or features of living systems that have a non-use value – an existence value and bequest value]	Moral satisfaction from and responsibility for existence and preservation for future generations of the marine habitats and species

3. Indicators for the socioeconomic assessment of the ecosystem services

This socioeconomic assessment of ES provides estimates for the benefit and value elements of the ES cascade model. It is based on an indicators' approach, which provides a systematic approach to measure diverse benefits and socioeconomic values derived by humans from the ES, which cannot be reduced to one (monetary) metrics. The developed indicators are based on the specifications of the benefits (see Table 1 of Section 2) and corresponding values, which were specified taking into account the definitions (Section 1). Only the direct benefits are included in the socioeconomic assessment to avoid double-counting of the benefits. The developed indicators also aim to keep explicit the links between the ES, corresponding benefits and socioeconomic values.

Relevant criteria, which were considered for setting the indicators (adapted from Link et al. (2009) and Hattam et al. (2015) according to relevance for the benefit and value indicators):

- Measurability: are there data available for the measurement and quantification of the indicator?
- Sensitivity: does the indicator allow detecting change in the value due to changes in the ES provision?
- Spatial and temporal scale: does the indicator have clear spatial and temporal scale?

For the value indicators the assessment focusses on providing monetary estimates. However other quantitative indicators are also indicated, which aim to show diversity of the values (e.g. created revenues to economic sectors and employment, contributions to physical and mental well-being) and human preferences towards ES in non-monetary terms, allowing broader assessment of the human well-being aspects. Such indicators, in many cases, require special data collection (surveys), and no uniform data are available for all the sea region countries. Therefore, only country-scale illustrations could be provided for such indicators based on available data.

The most appropriate monetary (welfare) measure is the 'economic value', measured by 'consumer surplus'[5] or people's willingness to pay for environmental change. Since special valuation studies are necessary to estimate the 'economic value', such data, in most cases, are not available, in particular for the whole sea region. Hence, other measurements, like market prices and data on socioeconomic impacts (e.g. employment and economic revenues), are used. It needs to be stressed however that these other ones are only proxies for the 'economic value' and allow measuring socioeconomic impacts, but not the 'economic value'.

The sea region scale estimates could be provided for selected ES. Table 2 summarises these ES and the developed benefit and value indicators. Other (non-monetary) indicators, which are illustrated based on country-scale data, are provided in Table 3.

The monetary indicators of the various ES are based on different assessment methods (e.g. market prices for provisioning ES; cost-based methods for regulating ES; benefit-based methods for cultural ES). It needs

[5] The monetary gain obtained by consumers because they are able to purchase a product for a price that is less than they would be willing to pay (the 'consumer surplus' is the difference between the consumer's total willingness to pay and the total amount they pay for the good).

to be taken into account when aggregating these estimates for assessing the socioeconomic impacts of policy scenarios.

The other (non-monetary) indicators (Table 3) are rather difficult to apply in light of assessing changes in the ES value due to changes in the ES provision (e.g. for assessing the impacts of policy scenarios). But they provide additional information, e.g. on spatial dimension of the ES benefits and societal preferences.

Table 2. The developed indicators of ES benefits and values for the sea region scale socioeconomic assessment of ES. (Source: Own work.) The assessments are provided in Section 4.2.

Ecosystem service	BENEFIT indicators	VALUE indicators
P1 Wild fish for human and domesticated animal nutrition	* Catch of relevant fish species (tons/year), by main species.	* Monetary (market) value of commercial sea fish catch (EUR/year) for relevant fish species (e.g. Herring, Sprat, Cod, Flounder). * Number of jobs (FTE*/year) and Added Value (EUR/year) in commercial fisheries.
P3 Fish cultivated by in-situ aquaculture *[part of P3]*	* Marine aquaculture production (tons/year); by relevant species.	* Monetary (market) value of the marine aquaculture production (EUR/year). * Number of jobs (FTE/year) and Added Value (EUR/year) in marine aquaculture.
RM1 Nutrient regulation (assimilation, storage and sequestration)	* Amount of nitrogen and phosphorus, which is discharged from human activities, assimilated, stored and/or sequestered by the marine habitats (kg/km2/y).	* Saved/avoided costs for nutrient treatment from human activities (EUR/year).
RM3 Carbon sequestration (assimilation, storage and sequestration)	* Amount of CO_2, which is emitted from human activities, assimilated, stored and/or sequestered by the marine habitats (t/km^2/y).	* Avoided costs of the damage to human welfare from carbon emissions (based on Market Value of carbon and/or 'Social Costs of Carbon' (SCC)) (EUR/y).
Cultural ES related to recreation (C1-C6)	* No of leisure visits to the sea (per visitor per year). * Share of users (visitors) in the total population.	* Monetary recreational benefits (EUR/year). The benefits cover various cultural ES, the values for the individual ES cannot be estimated. * Number of jobs (FTE/year) and Added Value (EUR/year) in sectors serving coastal tourism and recreation.
C7 Existence of habitats and species		* Relative importance (points out of 100) of the benefits from individual cultural ES, including C7.

* FTE – full-time equivalent.

Table 3. Non-monetary indicators of ES benefits and values, used for additional illustrations on the socioeconomic assessment of ES. (Source: Own work.) The assessments are provided in Section 4.3.

Ecosystem services	BENEFIT indicators	VALUE indicators
Recreational ES	* Most often visited sites for leisure at the sea	
Individual ES, covering all relevant ES	* Share of national population, attaching significance to the benefits of the individual ES.	* Relative importance (points out of 100) of the benefits from individual ES.

4. Socioeconomic assessment of the marine ecosystem services

The socioeconomic assessment aims to provide estimates on benefits and values of relevant ES and to demonstrate approaches for assessing changes in the ES value to measure well-being impacts of policy scenarios. Such an assessment requires linking the ecosystem components to the ES provision and further to the ES benefits and values. Although the work as part of the BLUES project focused on the socioeconomic assessments (the ES benefits and values), the linkages are considered when developing the socioeconomic assessment approach, including the indicators.

4.1. Link with the contributing ecosystem components and ecosystem service supply

The former HELCOM ES assessment approach includes a simple linkage between the ecosystem components and the ES supply, where the links between the contributing ecosystem components and the ES are assessed by presence/absence approach. The ecosystem components are defined based on HELCOM data system, hence provides a large set of largely overlapping components. Such an approach gives limited opportunity for linking the socioeconomic estimates to the ecosystem components, which is of particular importance for assessing the socioeconomic impacts of policy scenarios.

Further work has been done by HELCOM MetDev project and HOLAS 3 to develop quantitative estimates on the ES supply. The estimates cover provisioning and regulating ES. For the regulating ES the estimates have been developed with respect to selected marine habitats (Zostera marina, brown algae of Fucus sp., soft bottom sediments), ensuring clear and quantified link with the ecosystem components (for instance, phosphorus amount sequestered by soft bottom sediments). The given habitats have been selected based on availability of data for the sea region scale estimation of the ES supply. The ES supply rates have been developed based on existing scientific literature for the Baltic Sea, and these rates are combined with spatial data on the habitat distribution to provide spatial and quantified estimates on the ES benefits. This approach allows establishing the link between the ecosystem (components) and the benefits to humans. These bio-physical estimates of the ES supply are used for quantitative benefit indicators (see Section 3). However, further work is needed to cover all relevant ecosystem components, as well as to develop an approach for linking the ecosystem components to the supply of provisioning and cultural ES. Examples on possible approaches for assessing the links between the ecosystem components and the ES can be found in the sea region. An illustration for the approach from Latvia is provided in Box 1.

Box 1. Assessing contribution of the marine ecosystem components in the supply of (individual) ecosystem services (ES) – an illustration of the approach from Latvia.

Detailed information can be found in Armoškaite et al., (2020) (Armoškaite A., Purina I., Aigars J., Strate S., Pakalniete K., Frederiksen P., Schroeder L., Hansen H.S. (2020) Establishing the links between marine ecosystem components, functions and services: An ecosystem service assessment tool. Ocean & Coastal Management, Vol.193(2020), 105229. https://doi.org/10.1016/j.ocecoaman.2020.105229).

A marine ES assessment tool has been developed for the Latvian marine waters as part of the BONUS BASMATI project (https://bonusbasmati.eu/), which provides an assessment of contribution of the marine ecosystem components in the supply of ES (called as the ESA4MSP tool). All ES relevant for the national marine waters are included. The ES list is based on CICES classification (v5.1). The tool covers all marine biotopes and species, besides birds and mammals, which are characteristic for the Latvian marine waters. They are combined in habitats according to the HELCOM HUB classification. Structure of the tool follows the ES cascade model, linking the ecosystem components via their functions to the ES, therefore the list of ES includes the final ES only. The links have been established by marine scientists, based on best available national knowledge and data (Figure A). The contribution has been assessed in relative terms, diving 100% among the contributing components, for each element of the tool (Habitats, Functions, ES), thus the tool consists of three matrixes, which were filled based on expert knowledge. Therefore, the tool allows calculating relative contribution of the habitats to the supply of (each) ES. The linkages and contributions are visualised (Figure A) using a linkage diagram (Sankey diagram using Python programming language). These results can be linked further to the ES benefits for assessing well-being impacts from changes in the ecosystem components and ES supply (e.g. for policy scenarios).

The tool is used for the national marine ES assessments to support various policy needs (in particular, related to MSFD and MSP). At the same time, the national work is conducted also for developing the bio-physical estimates on the ES provision, which are used for the socioeconomic assessments of the marine ES (AKTiiVS, 2022).

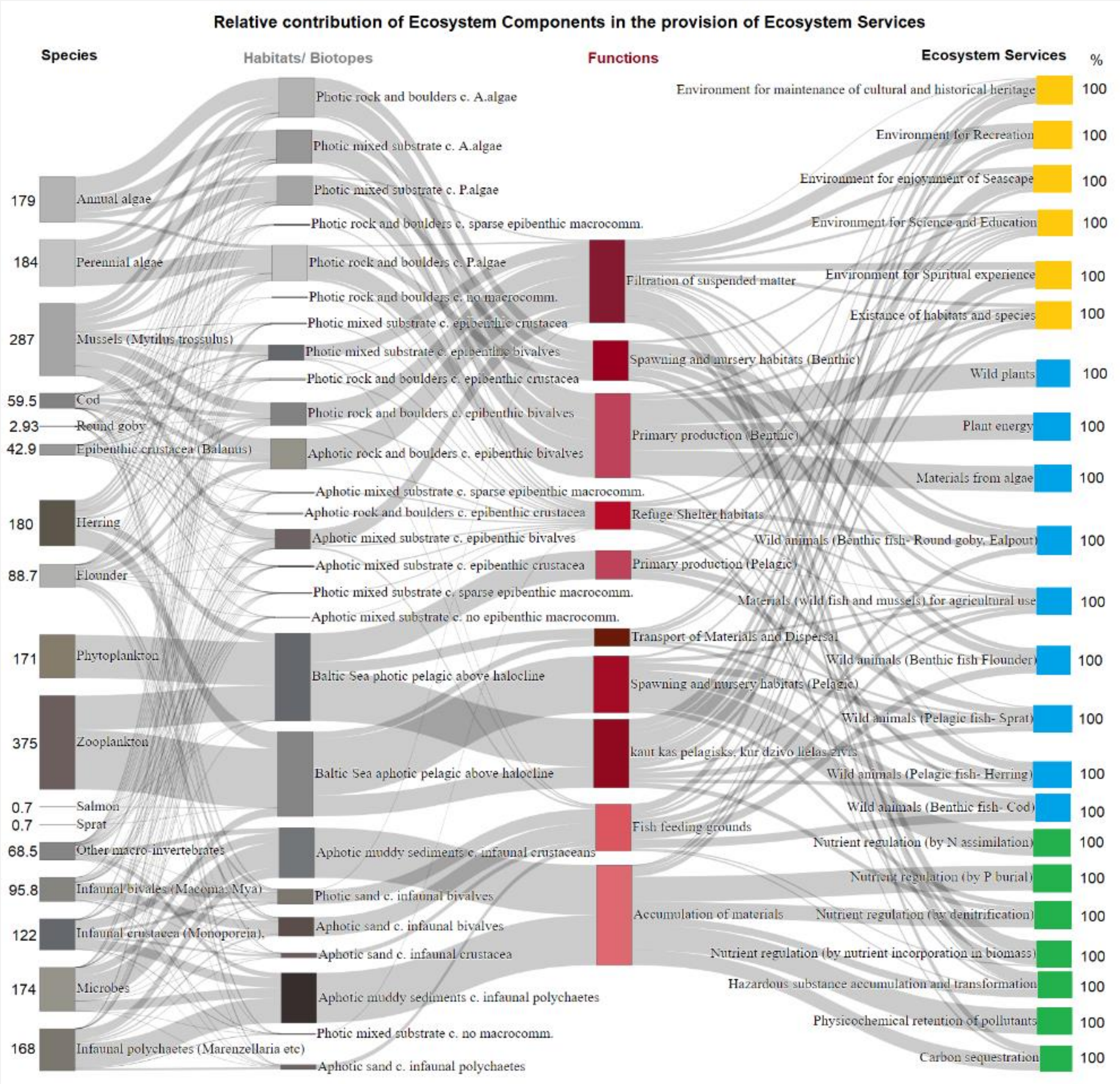


Figure A. Assessment of the contribution of marine ecosystem components in the ES provision – an illustration from the ESA4MSP tool for the Latvian marine waters (Armoškaite et al., 2020).

4.2. Socioeconomic assessment of relevant marine ES

This section summarises the developed estimates for the benefit and values indicators. For each covered ES the used data and the estimation approach is described, and also confidence of the estimates is indicated, based on the categories presented in Table 4. The confidence is assessed from the perspective of input data quality, not evaluating the used approach.

Table 4. Applied categories for assessing confidence of the socioeconomic estimates. (Source: Own work.)

Low confidence	There are many factors creating variability in the estimated subject, no sufficient empirical data to estimate this variability; estimate is based on scarce data, heavily relying on extrapolations and assumptions
Moderate confidence	The estimate is based on some empirical data, but involves largely extrapolations and/assumptions
Good confidence	The estimated is based on sufficient empirical data, with only minor extrapolations and/or assumptions
High confidence	The estimated is based fully on empirical recent data, practically no extrapolations or assumptions

P1 Wild fish for human and domesticated animal nutrition

Link with the ES provision is characterised in Table 5. It is based on bio-physical estimate of fish catch (see the benefit indicator) for relevant fish species. Assessment of the ecosystem components, contributing to the provision of this ES, is not available for the sea region. The socioeconomic assessment is summarised in Table 6.

Table 5. Link with the ES provision for the ES P1 "Wild fish for human and domesticated animal nutrition". (Source: ES supply analysis for HOLAS III.)

Assessment elements	Specification	Data sources
Bio-physical (benefit) estimates	Catch tons/year; by relevant species (Herring, Sprat, Cod, Flounder).	Based on ICES landing data (by the sea regions).

Table 6. Socioeconomic assessment for the ES P1 "Wild fish for human and domesticated animal nutrition". (Source: Own work.)

Assessment elements	Benefits	Corresponding values
Indicators	* Catch of relevant fish species (tons/year), by main species.	* Monetary (market) value of commercial sea fish catch (EUR/year) for relevant fish species (Herring, Sprat, Cod, Flounder). * Number of jobs (FTE/year) and Added Value (EUR/year) in commercial fisheries.
Estimation approach	Based on ICES landing data (by the sea regions).	For the monetary indicator: Market price (based on average retail and landing prices EUR/kg of fish products for relevant fish species). For the AV and employment indicators: Country scale statistical data.
Data sources	Estimates for HOLAS 3 (ES supply analysis).	For the monetary indicator: European Market Observatory for Fisheries and Aquaculture Products (EUMOFAP) (available at https://www.eumofa.eu/data). For the AV and employment indicators: Scientific, Technical and Economic Committee for Fisheries (STECF) The 2021 Annual Economic Report on the EU Fishing Fleet (STECF 21-08).

The monetary value of nutrition benefits is estimated based on the market prices of fish products for relevant fish species. The approach is based on the assumption that the market price reflects the value attached by consumers to the good in question. Such estimate is a proxy for the value of the ES benefits. It should be taken into account also that such estimate accounts also the contribution of human capital, might cover also the "cultural" value of fish (not only the nutrition value). An assessment based on, for instance, “fish (resource) rent”[6] would be more conceptually sound, however such data are not available for the sea region.

Data on the retail/consumption prices are taken from European Market Observatory for Fisheries and Aquaculture Products (EUMOFAP) (available at https://www.eumofa.eu/ad-hoc-queries). Data for the Baltic Sea are extracted from this source. The price data for the most common fish products in the sea region countries are used. An interval price is created for each species, where the intervals are determined primarily by the prices of various products (see Table 7 for specification of products for each species). In some cases, the price intervals are impacted also by the price differences in the countries (e.g. for cod). These prices are multiplied by the catch of relevant fish species (tons/year) in the Baltic Sea (based on ICES data) to calculate the monetary benefits of this ES. Results are provided in Table 8.

The wild fish is used also for domesticated animal nutrition (mainly sprat and herring). For instance, in Germany even up to 90% of the catch of herring and sprat is used for such a purpose. The benefits for animal nutrition would be better reflected by the landing price rather than the retail price of fish products, and the landing prices are considerably lower (see Table 7). There is no data for the whole sea region on the proportion of the total catch used for the animal nutrition. The benefit estimate is calculated assuming that 50% of the catch of sprat and herring is used for the animal nutrition, applying the landing price for this proportion. Table 8 provides the estimated benefits for the Baltic Sea region from this ES. Confidence of this estimate is moderate, since it is calculated based on a range of prices for various fish products, but misses actual data on shares of the various products in the consumption.

Table 7. Unit values (prices) of the monetary value indicator for the ES P1 “Wild fish for human and domesticated animal nutrition”. (Source: Based on EUMOFAP data, available at https://www.eumofa.eu/data.)

Fish species and their products	Retail/consumption price EUR/kg (based on data for 2020)	Landing price EUR/kg (based on data for 2020)
Baltic herring and its products (fillets, in oil, in sauce, canned, rollmops)	3-7.5	0.20
Sprat/sardine (fresh, canned, in oil)	2-7.5	0.17
Cod (fresh, frozen) and its products (whole, gutted, fillets)	6-9	3.0
Flounder (fresh, whole or gutted)	3 (an average price in the Baltic Sea for 2019-2021)	1.4

Table 8. Monetary benefits of the ES P1 “Wild fish for human and domesticated animal nutrition” for the Baltic Sea countries. (Source: Own calculation.) The colour denotes confidence (moderate).

Fish species	Catch in the Baltic Sea, tons/year[1]	Applied market price, EUR/kg[2]	Total monetary benefits, million EUR/year[3]
Atlantic herring	326 821	3-7.5 EUR (50%) and 0.20 EUR (50%)	523 – 1 259
European sprat	285 500	2-7.5 EUR (50%) and 0.17 EUR (50%)	310 – 1 095

[6] The harvest of fish stocks provides economic surpluses, which, in a well-managed fishery, are distributed between fishermen (as producers) and seafood consumers. Taken together, producer and consumer surpluses are the economic measure of the value. Producer surplus is equivalent to the revenues earned from selling catch net of all costs of fishing. Consumer surplus is evaluated as what consumers are willing to pay for seafood, less what they actually pay in the market. One element of the producer surplus is known as the “resource rent”. The resource rent is the cost of fish utilized as an input in the production of seafood as a commodity. Resource rent implies that fish have a price, although nature does not charge fishermen this price when fish are removed from their habitat. The resource rent can be interpreted as the value of the ecosystem “service” as embodied in wild fish stocks, per se.

Fish species	Catch in the Baltic Sea, tons/year[1]	Applied market price, EUR/kg[2]	Total monetary benefits, million EUR/year[3]
Atlantic cod	19 585	6-9 EUR	118 – 176
European flounder	15 377	3 EUR	46
Total			**997 – 2 576**

[1] ICES landing data, average for 2016-2021. [2] Based on the price data from Table 7. [3] Calculated by multiplying [1] and [2].

Table 9 provides data for the ES indicators on added value and employment. Since actual data for the countries are used the confidence is high.

Table 9. Data on the added value and employment indicators for the ES P1 "Wild fish for human and domesticated animal nutrition". (Source: STECF (2021).) The colour denotes confidence (high).

Country	Gross value added (GVA) (million €)	Number of persons employed (full-time equivalent)
Denmark	15.3	148
Estonia	8.1	326
Finland	17.4	258
Germany	5.2	540
Latvia	7.6	262
Lithuania	1.9	91
Poland	23.2	2157
Russia	no data	no data
Sweden	43.3	286
Total	**122**	**4068**

P3 Fish cultivated by in-situ aquaculture

Link with the ES provision is characterised in Table 10. It is based on bio-physical estimate of the marine aquaculture production (see the benefit indicator). Assessment of the ecosystem components, contributing to the provision of this ES, is not available. The socioeconomic assessment is summarised in Table 11.

Table 10. Link with the ES provision for the ES P3 "Fish cultivated by in-situ aquaculture". (Source: ES supply analysis for HOLAS III.)

Assessment elements	Specification	Data sources
Bio-physical (benefit) estimates	Marine aquaculture production (tons/year); by relevant species.	STECF 20-12 - Aquaculture economic data tables.xlsx (https://stecf.jrc.ec.europa.eu/reports/economic).

Table 11. Socioeconomic assessment for the ES P3 "Fish cultivated by in-situ aquaculture". (Source: Own work.)

Assessment elements	Benefits	Corresponding values
Indicators	Marine aquaculture production (tons/year); by relevant species.	* Monetary (market) value of the marine aquaculture production (EUR/year). * Number of jobs (FTE/year) and Added Value (EUR/year) in the marine aquaculture.
Estimation approach	Data STECF 20-12 - Aquaculture economic data tables.xlsx.	For the monetary indicator: Market price (based on prices EUR/kg of aquaculture products). For the AV and employment indicators: Country scale statistical data.
Data sources	Estimates for HOLAS 3 (ES supply analysis).	For the monetary indicator: European Market Observatory for Fisheries and Aquaculture Products (EUMOFAP) (available at https://www.eumofa.eu/data). For the AV and employment indicators: STECF (2020).

The monetary value is estimated based on the market prices of the marine aquaculture production. The approach is based on the assumption that the market price reflects the value attached by consumers to the good in question. Such estimate is a proxy for the value of the ES benefits. It should be taken into account also that such estimate accounts also the contribution of human capital. However, it is applicable for the sea region taking into account the available data.

Data on the market prices (Table 12) are taken from the European Market Observatory for Fisheries and Aquaculture Products (EUMOFAP) (available at https://www.eumofa.eu/aqualculture-yearly-comparison-between-ms). Data for the Baltic Sea are extracted from this source. The price data for the most common aquaculture products in the sea region countries are used. An interval price is created for each species/product (Table 12), where the intervals are determined by sales and retail prices and also the price differences in the countries. These prices are multiplied by the production (tons/year) to calculate the monetary benefits of this ES. Confidence of this estimate is moderate, since it is calculated based on a range of prices for various products, but misses actual data on shares of the various products in the consumption.

Table 12. Monetary benefits of the ES P3 "Fish cultivated by in-situ aquaculture" for the Baltic Sea countries. (Source: Own calculation.) The colour denotes confidence (moderate).

Species/ products	Production in the Baltic Sea, tons/year (average for 2016-2018)[1]	Applied market price, EUR/kg[2]	Total monetary benefits, million EUR/year[3]
Mussel	21 838	2-5 EUR (aquaculture sales price – fish retail price)	44-109
Trout	46 022	6-19 EUR (fish retail/ consumption prices (2021) in various countries for various products)	276-874
Crustaceans	2 297	27 EUR (aquaculture sales price; average for the Baltic Sea from 2018-2020)	62
		TOTAL:	**382-1046**

[1] Data STECF 20-12 - Aquaculture economic data tables.xlsx; average for 2016-2018 (data for 2018 are the most recent available data in November of 2022). [2] Based on EUMOFAP data. [3] Calculated by multiplying [1] and [2].

Table 13 provides data for the ES indicators on added value and employment.

Table 13. Data on the added value and employment indicators for the ES P3 "Fish cultivated by in-situ aquaculture". (Source: STECF (2020).) The colour denotes confidence (high).

Country	Gross value added (GVA) (million €)	Number of persons employed (FTE)
Denmark	21.2	117
Estonia	0	0
Finland	19.8	111
Germany	confidential	confidential
Latvia	0	0
Lithuania	0	0
Poland	0	0
Russia	no data	no data
Sweden	0.8	21
Total	**41.8**	**249**

RM1 Nutrient regulation

Link with the ES provision is characterised in Table 14. It is based on bio-physical estimates of nutrient assimilation, storage and sequestration (see the benefit indicator) by selected marine habitats, where the data were available for the sea region scale assessment (developed as part of the ES supply analysis for HOLAS 3). The socioeconomic assessment is summarised in Table 15.

Table 14. Link with the ES provision for the ES RM1 "Nutrient regulation". (Source: ES supply analysis for HOLAS 3.)

Assessment elements	Specification	Data sources
Link with the ecosystem components (contributing to the ES provision)	Illustrations for selected components: Zostera marina, brown algae of Fucus sp., soft bottom sediments (mud and mixed).	Estimates for HOLAS 3 (ES supply analysis).
Bio-physical (benefit) estimates	Amount of nitrogen and phosphorus assimilated, stored and sequestered by the marine habitats (kg/km^2/y). Total estimated area of the habitats in the Baltic Sea.	

Table 15. Socioeconomic assessment for the ES RM1 "Nutrient regulation". (Source: Own work.)

Assessment elements	Benefits	Corresponding values
Indicators	Amount of nitrogen and phosphorus, which is discharged from human activities, assimilated, stored and sequestered by the marine habitats (kg/km^2/y).	Saved/avoided costs for nutrient treatment from human activities (EUR/year).
Estimation approach	Estimates on N and P assimilation, storage and sequestration rates by various habitats based on literature for the Baltic Sea. Habitat areas estimated based on HELCOM data.	Estimated based on replacement cost method – costs of nutrient treatment by WWTP. The used unit value (costs): 6.5 EUR/kg of N and 20 EUR/kg of P. It is multiplied by the assimilation, storage or sequestration rate and the total habitat area for calculating the benefits to humans provided by that habitat.

Assessment elements	Benefits	Corresponding values
Data sources	Estimates for HOLAS 3 (ES supply analysis).	Literature review (publications from the Baltic Sea region). Data from Hautakangas et al. (2014)[7].

For the monetary value estimate the Waste Water Treatment Plant (WWTP) abatement costs are used to derive a proxy for the benefits to humans from the nutrient abatement. The approach is based on an assumption that the value of a unit abatement in any pollution source is at least worth the savings obtained when not having to make the similar abatement elsewhere.

The WWTP is used as a benchmark abatement technology. Data on abatement levels and costs are available relatively well. For instance, Hernández-Sancho et al. (2010) used a shadow price method for estimating the benefits for the key pollutants emitted by a WWTP: phosphorus (P), nitrogen (N), suspended solids, BOD and DOD. Using cost structures of 43 WWTPs and the relative differences in abatement levels for individual pollutants in them, they were able to derive statistical relations between the shadow costs of the individual pollutants. They can be interpreted as empirical allocations of operational costs of the facilities between the pollutants. The shadow costs also depend strongly on the assumed value of treated, pure water. For this, the researchers use alternative benchmarks.

The most important pollutants in terms of avoided costs are N and P. Depending on the benchmark value for purified water, the obtained shadow values for N range between 4.6 €/kg and 65.2 €/kg and for P between 7.5€/kg and 103.4 €/kg. The results hinge on the overall value of purified water for which the assumptions are not made explicit. However, the relative weights between N and P are solid.

The alternative and a more straightforward way, would be to use the unit abatement costs assessed for the Baltic Sea WWTPs directly. The challenge here is the lack of studies that distinguish between the abatement costs of various pollutants. This, of course, is very difficult as the capital and labour costs are the most important term of costs and they are the burden of the entire facility. For instance, Ruiz-Rosa et al. (2016) break down the abatement costs carefully in terms of the technologies used but do not separate the costs of various pollutants. The WWTP abatement costs behind the BALTCOST model (Hasler et al., 2012) estimates the total costs of improving from primary to secondary and to tertiary treatment, and the potential for this in various sea basins. Then, it assigns P and N abatement levels for these three. From these it is able to derive total costs of alternative allocations between the three technologies. Implicitly, such an approach would make it possible to express the nutrient abatement functions of N and P.

Gren (2008) and Hautakangas et al. (2014) are studies providing such estimates for the Baltic Sea WWTP abatement for both N and P. These cannot be directly compared, however.

Gren (2008) provides estimates for marginal abatement costs for N and P but it is not explicitly shown how they are derived. For N the estimated marginal abatement costs vary between 12 and 79 €/kg, depending on the country, while they vary for P between 41 and 330 €/kg. The average costs are not reported. Hautakangas et al. (2014) provides the most transparent methodology for their assessment. They estimated the average abatement costs for N and P, accounting size of the WWTP and nutrient reduction level. Selected estimates illustrating the variations in these costs are provided in Table 16. When comparing these estimates of the average abatement costs with the results from Gren (2008) on the marginal abatement costs for similar facilities and removal rates, the results of Hautakangas et al. (2014) are slightly lower.

For the purposes of estimating the benefits obtained with the WWTP abatement so far, it would be justified to use the average abatement costs instead of the marginal abatement costs. The marginal

[7] Hautakangas S., Ollikainen M., Aarnos K. and Rantanen P. (2014) Nutrient abatement potential and abatement costs of waste water treatment plants in the Baltic Sea region. Ambio, 43(3), 352-360. https://doi.org/10.1007/s13280-013-0435-1.

abatement cost would give an indirect estimate of the avoided cost of not having to abate the very last unit of the pollutant. However, the essence of the approach is to evaluate how much resources have been allocated on wastewater treatment in total. Hence, the average abatement costs are the correct metric. This is also the approach taken, for instance, by Hernández-Sancho et al. (2010).

Of the studies analysed, the values provided by Hautakangas et al (2014) were found the most suitable for the sea region assessment. It is justified to use the highest abatement levels to represent the avoided costs. In Finland and Sweden, for instance, such costs would then be 4.7 €/kg for N and 15.2 €/kg for 90% abatement level for N and 95% for P. In many parts of the Baltic Sea, the most effective WWTPs would be better represented by the 70% abatement level for N and 90% for N, associated with average abatement costs of 4.3 €/kg for N and 13.6 €/kg for P. In 2021 prices these costs would correspond to 6.7 €/kg and 6.1 €/kg for N and 21.7 €/kg and 19.4 €/kg for P (see Table 16).

Table 16. Selected estimates on the average nutrient abatement costs from Hautakangas et al. (2014).

Estimates from Hautakangas et al. (2014)		Estimate in 2021 prices
Abatement costs for N (EUR/kg)		
for middle-size WWTP[1], 70% reduction rate	4.3 €	6.1 €
for largest-size WWTP[2], 90% reduction rate	4.7 €	6.7 €
Abatement costs for P (EUR/kg)		
for middle-size WWTP[1], 90% reduction rate	13.6 €	19.4 €
for largest-size WWTP[2], 95% reduction rate	15.2 €	21.7 €

[1] 80 000 – 200 000 PE. [2] > 500 000 PE.

Based on the data from Hautakangas et al. (2014) (calculated in 2021 prices) **the estimates used for the sea region assessment are 6.5 EUR/kg for N and 20 EUR/kg for P.** These estimates were compared with assessments from other studies[8], and it was concluded that they could indicated rather the lower bound of the benefits. It is important to note that these benefit estimates do not take stance to the effects of these pollutants in the environment. They should be seen as the cost benchmark: this, at least, will be benefited by avoiding the abatement from the cheapest possible sources of pollution.

The unit values are multiplied by the amount of nitrogen and phosphorus assimilated, stored and sequestered by the marine habitats (kg/km^2/y) to calculate the monetary benefits. The assimilation, storage and sequestration rates by various habitats have been estimated as part of the ES supply analysis for HOLAS 3 based on scientific literature for the Baltic Sea (Table 17). The ES includes assimilation, storage and sequestration, which is performed by various habitats, and the benefits can be calculated for each "sub-service". They should not be summed up from the perspective of estimating the final benefits, since they account the same substance in various stages of the substance cycling through the ecosystem. Accounting sequestration only would be the most appropriate way for estimating the final benefits. However, the benefits of "sub-services" by contributing habitats demonstrate the role and value of the various ecosystem components for the human well-being.

Table 18 provides the calculated monetary benefits for the "sub-services" provided by three important habitat types in the Baltic Sea (where the ES supply rates were available). The benefits are calculated as the total benefits per year, accounting the average supply rates and the total estimated habitat area in the Baltic Sea. Confidence of the estimates is moderate, since they are based on an average unit cost for all Baltic Sea countries, but the costs differ in reality depending on various factors (like size of a

[8] For instance, the study AKTiiVS (2022) provides the average 16 EUR/kg (for both nutrients), which was calculated based on actual data from all tertiary treatment plants in Latvia (based on data for 2018). Centrum Balticum (2018) used 19 EUR/kg of N and 86 EUR/kg of P.

wastewater treatment plant, the nutrient reduction level). In addition, the benefits are calculated also per 1 km^2 of the habitat area, using also the minimum and maximum supply rates. The result shows considerable differences in the benefits per area unit, depending on the supply rate.

Table 17. The used N and P assimilation, storage and sequestration rates ($t/km^2/y$) by various marine habitats (an average for the Baltic Sea, minimum and maximum rates in parentheses). (Source: ES supply analysis for HOLAS 3.)

Habitat	Zostera marina	brown algae of Fucus sp.	soft bottom sediments (mud and mixed)
Area in the Baltic Sea (km^2)	**5 381**	**6 926**	**316 134**
Nitrogen (N_{tot}) assimilation	19.7 (13.1-23.2)	0.46 (0.2-1.31)	
Nitrogen (N_{tot}) storage*	78.5 (22.5-108.7)	0.27 (na)	
Nitrogen (N_{tot}) sequestration (includes burial and denitrification)			2.7 (1.1-5.8)
Phosphorus (P_{tot}) assimilation	2 (1.31-2.32)	0.03 (0.01-0.09)	
Phosphorus (P_{tot}) storage*	7.8 (2.3-10.9)	0.02 (na)	
Phosphorus (P_{tot}) sequestration			0.8 (0.2-2.2)

* The storage does not have temporal scale.

Table 18. Monetary benefits (EUR/y) of the ES RM1 "Nutrient regulation" provided by Zostera marina, Fucus sp and soft bottom sediments in the Baltic Sea. (Source: Own calculation.) The colour denotes confidence (moderate).

Habitat	Zostera marina		Fucus sp.		Soft bottom sediments	
	million EUR/y	EUR/km^2/y [1]	million EUR/y	EUR/km^2/y [1]	million EUR/y	EUR/km^2/y [1]
Nitrogen (N_{tot}) assimilation	**690**	128 228 (85 150 – 150 800)	**21**	2 998 (1 294 – 8 522)		
Nitrogen (N_{tot}) storage[2]	**2 744**	510 017 (146 250 – 706 550)	**12**	1 732		
Nitrogen (N_{tot}) sequestration (includes burial and denitrification)					**5 446**	17 266 (7 345 – 37 830)
Phosphorus (P_{tot}) assimilation	**212**	39 454 (26 200 – 46 400)	**4**	642 (260 – 1 800)		
Phosphorus (P_{tot}) storage[2]	**844**	156 926 (46 000 – 218 000)	**3**	369		
Phosphorus (P_{tot}) sequestration					**4 967**	15 711 (4 200 – 44 200)

[1] The interval is based on minimum and maximum supply rates (t/km^2). [2] Storage does not have temporal scale.

RM3 Carbon sequestration

Link with the ES provision is characterised in Table 19. It is based on bio-physical estimates of carbon assimilation, storage and sequestration (see the benefit indicator) by selected marine habitats, where the data are available for the sea region scale assessment (developed as part of the ES supply analysis for HOLAS 3). The socioeconomic assessment is summarised in Table 20.

Table 19. Link with the ES provision for the ES RM3 "Carbon sequestration". (Source: ES supply analysis for HOLAS 3.)

Assessment elements	Specification	Data sources
Link with the ecosystem components (contributing to the ES provision)	Illustrations for selected components: Zostera marina, brown algae of Fucus sp., soft bottom sediments (mud and mixed).	Estimates for HOLAS 3 (ES supply analysis).
Bio-physical (benefit) estimates	Amount of assimilated, stored and sequestered by the marine habitats CO_2 ($t/km^2/y$). Total estimated area of the habitats in the Baltic Sea.	

Table 20. Socioeconomic assessment for the ES RM3 "Carbon sequestration". (Source: Own work.)

Assessment elements	Benefits	Corresponding values
Indicators	* Amount of CO_2, which is emitted from human activities, assimilated, stored and sequestered by the marine habitats ($t/km^2/y$).	* Avoided costs of the damage to human well-being from carbon emissions (EUR/year).
Estimation approach	Estimates on CO_2 assimilation, storage and sequestration rates by various habitats based on literature for the Baltic Sea. Habitat areas estimated based on HELCOM data.	Estimated using value transfer from literature, based on the 'social costs of carbon' (SCC). The used unit value (costs): 40-100 EUR/t of CO_2. It is multiplied by the assimilation, storage or sequestration rate and the total habitat area for calculating the benefits to humans provided by that habitat.
Data sources	Estimates for HOLAS 3 (ES supply analysis).	Literature review. Data from Wang et al. (2019) and High-Level Commission on Carbon Prices (2017).

The storage of CO_2 in the various components of marine systems provides an important service in regulating atmospheric CO_2 concentration since it prevents the absorbed CO_2 from immediately contributing to the greenhouse effect, thus slowing climate change (Melaku Canu et al., 2015). Although the socioeconomic impacts of climate change are not yet well understood, it is thought that it will impact resource based sectors depending on provisioning ES as well as human health such as heat stress, heart related disorders and infections due to increased extreme weather conditions and limited food supplies (Wang et al., 2019). Hence, the benefit from the carbon storage service is climate change mitigation and sustained living conditions essential for human welfare.

There are also possible negative adverse impacts on human welfare due to this ES. For the marine environment, the increasing concentrations of CO_2 are resulting in changes of water pH levels making the marine environment more acidic and inhibiting growth of some flora and fauna (Luisetti et al., 2013; Melaku Canu et al., 2015; Armstrong et al., 2019). Ocean acidification will decrease flows of ES, and, in the long run, will have a negative effect on human health and welfare due to negative influence on natural products for consumption as well as interaction with the marine environment (Fleming et al., 2014; Wang et al., 2019). These possible adverse impacts are not included in the given assessment.

While there is no market for carbon storage in the marine ecosystems, values connected to carbon storage can be taken from carbon markets, national carbon taxes or from estimates inferring the value of stored carbon (or the costs of carbon to society) such as the 'social costs of carbon' (SCC), or the shadow price of carbon. Carbon values are much debated with many estimates for long-run damage costs of climate change and abatement costs. It is recognised that the value is highly uncertain, depending on the underlying climate scenarios, the carbon price used and its change over time, which depends on the assumed price growth rates and discount rates (Armstrong et al., 2019).

The carbon prices come from charges for carbon emissions that may come in a shape of a carbon tax based on the polluter pays principle or a cap and trade scheme whereby the government introduces permits and companies participate in emissions trading systems, trading carbon emission allowances. The world's largest carbon emission trading scheme is the European Union Emission Trading Scheme (EU ETS). It is designed to steadily reduce the level of carbon emissions over time and therefore the value of an allowance is expected to increase over time. There has been an increasing trend in the carbon price of the EU ETS since 2013, reaching the average carbon price of around 23 EUR/t CO_2 in 2019 (World Bank, 2019). Since that the price has increased considerably reaching its highest level close to 100 EUR in August of 2022 (Figure 4). The EU ETS carbon price has been used in valuation studies (e.g. in Armstrong et al. (2019)), enabling comparison between results.

High-Level Commission on Carbon Prices (2017), which provides recommendations on the carbon price levels focusing on the carbon pricing instruments, concludes that the explicit carbon-price level consistent with achieving the Paris temperature target is at least 40-80 USD/t CO_2 by 2020 and 50-100 USD/t CO_2 by 2030, provided a supportive policy environment is in place.

Figure 4. Changes in the carbon price in the EU ETS since January of 2019. (Source: https://tradingeconomics.com/commodity/carbon.) Note. The price is shown on Y axis as EUR/t of CO_2.

The question whether a limited market will sufficiently take into account the full cost of carbon emissions has led to substantial work to estimate the SCC. The SCC is the estimate of monetary value of the damage done from the emission of one more ton of carbon at some point in time (Melaku Canu et al., 2015), or, in other words, it is the marginal damage cost of 1 ton of carbon emitted. The SCC signals what society should be willing to pay to avoid the future damage caused by incremental carbon emissions. Models developed to estimate the SCC are known as integrated assessment models, which aim to capture the linkages between greenhouse gas emissions, greenhouse gas atmospheric concentrations, temperature change, and monetary costs of climate change damage to society (Melaku Canu et al., 2015). Therefore, the SCC can be seen as a more appropriate welfare measure for the value of this ES.

Value transfer method has been widely applied to value this ES using social or shadow price of CO_2 as a proxy of the value (Luisetti et al., 2013; Beaumont et al., 2014; Melaku Canu et al., 2015; Zarate-Barrera and Maldonado, 2015). There are studies using SSC (Beaumont et al., 2014; Zarate-Barrera and Maldonado, 2015), but also using both – the carbon market price from EU ETS and the SSC from literature forming an interval for the carbon value (e.g. in Armstrong et al. (2019)).

The estimate used for this assessment is based on value transfer approach using the SSC. The SCC mean value of 54.7 USD (50 EUR)/t CO_2 based on meta-analysis of literature by Wang et al. (2019), gathering 578 estimates of SCC from 58 studies, is used as the basis. Such SCC value is applied also in other studies (e.g. in Armstrong et al. (2019) based on ANON (2016)). Such estimate calculated in the 2021 prices makes around 70 EUR/t of CO_2. **An interval value of 40-100 EUR/t of CO_2 is used for the assessment to account for uncertainties.** It is consistent with the High-Level Commission on Carbon Prices (2017) conclusion on the carbon-price level of 50-100 USD/t CO_2 by 2030.

The unit values are multiplied by the amount of CO_2 assimilated, stored and sequestered by the marine habitats (t/km^2/y) to calculate the monetary benefits. The assimilation, storage and sequestration rates by various habitats have been estimated as part of the ES supply analysis for HOLAS 3 based on literature for the Baltic Sea (Tables 21). The ES includes assimilation, storage and sequestration, which is performed by various habitats, and the benefits can be calculated for each "sub-service". Like for the nutrient regulation, they should not be summed up from the perspective of estimating the final benefits, and accounting sequestration only would be the most appropriate way for estimating the final benefits. However, the benefits of "sub-services" by contributing habitats are calculated to show their role and value for the human well-being. Table 22 provides the calculated monetary benefits for the "sub-services" provided by three important habitat types in the Baltic Sea (where the ES supply rates were available). The benefits are calculated as the total benefits per year, accounting the average supply rates and the total estimated habitat area in the Baltic Sea. Confidence of the estimate is moderate, since it involves transferring the damage costs values from literature. In addition, the benefits are calculated also per 1 km^2 of the habitat area, using also the minimum and maximum supply rates. The result shows considerable differences in the benefits per area unit, depending on the supply rate.

Table 21. The used CO_2 assimilation, storage and sequestration rates (t/km^2/y) by various marine habitats (an average for the Baltic Sea, minimum and maximum rates in parentheses). (Source: ES supply analysis for HOLAS 3.)

Habitat	Zostera marina	brown algae of Fucus sp.	soft bottom sediments (mud and mixed)
Area in the Baltic Sea (km^2)	**5 381**	**6 926**	**316 134**
CO_2 assimilation	1043 (692-1226)	31 (13.4-88.1)	
CO_2 storage*	4145 (1189-5744)	17.9 (na)	
CO_2 sequestration	82 (10-129)		47.8 (29.4-91.8)

* The storage does not have temporal scale.

Table 22. Monetary benefits (EUR/y) of the ES RM3 "Carbon sequestration" provided by Zostera marina, Fucus sp and soft bottom sediments in the Baltic Sea. (Source: Own calculation.) The colour denotes confidence (moderate).

	Zostera marina		Fucus sp.		Soft bottom sediments	
Sub-services	**million EUR/y**	**EUR/km^2/y [1]**	**million EUR/y**	**EUR/km^2/y [1]**	**million EUR/y**	**EUR/km^2/y [1]**
CO_2 assimilation	**224-561**	41 700 – 104 251 (27 692 – 122 607)	**8.6-21.5**	1 240 – 3 099 (537 – 8 813)		
CO_2 storage[2]	**892-2231**	165 815 – 414 538 (47 563 – 574 355)	**5-12.4**	717 – 1 791 (na)		
CO_2 sequestration	**18-44**	3 293 – 8 233 (408 – 12 918)			**604-1510**	1 910 – 4 776 (1 174 – 9175)

[1] The first interval is based on the applied unit price range (40-100 EUR/t), the second interval using also the minimum and maximum supply rates (t/km^2). [2] The storage does not have temporal scale.

Cultural ecosystem services related to recreation (C1-C6)

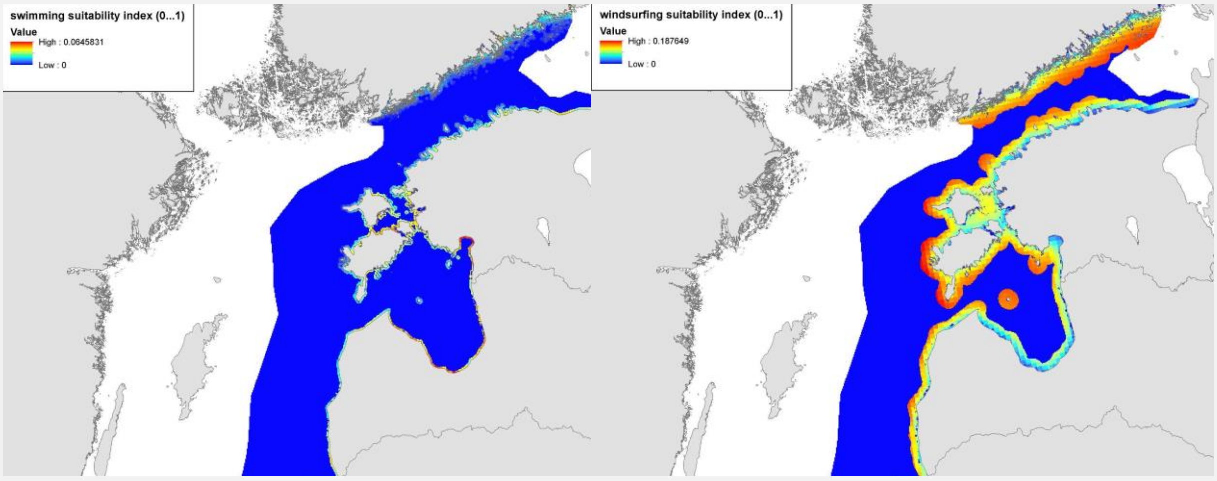
Assessment of the ecosystem components, contributing to the provision of the cultural ecosystem services (CES), is not available for the sea region. Recent studies in the sea region illustrate various approaches and outcomes. For instance, as part of a study conducted in the frame of MAREA project

(Forsblom et al., 2022) relevant data layers were combined to produce a coastal suitability index to spatially represent the suitability of Estonian, Latvian and Finnish coastlines for practising different recreational activities (Box 2). An assessment on the contribution of relevant components of the marine environment to deriving benefits from CES is provided by AKTiiVS (2022), where relative importance of the components has been assessed based on societal preferences, collecting data from a national survey in Latvia (Box 3). The results reveal that around 50% of the contribution can be attributed to various biotic components of the marine ecosystem (e.g. linked to marine plants and species, regulating ecosystem services).

Box 2. Mapping suitability of coastlines for practising different recreational activities in Estonia, Latvia and Finland.

A study conducted in the frame of Central Baltic Programme 2014-2020 project "From marine ecosystem accounting to integrated governance for sustainable planning of marine and coastal areas" (MAREA) (http://marea.balticseaportal.net/). Information from Forsblom L., Kotta J., Virtanen E., Nurmi M., Kallio N., Barboza F.R., Aps R., Kotta I., Jänes H., Orav-Kotta H., Szava-Kovats R., Lees L., Kõivupuu A., Loite S., Herkül K., Ruskule A., Veidemane K., Reķe A., Kuosa H., Lai T.Y., Jernberg S. (2022) D.T1.1.1. High-resolution maps on the intensity and extent of ecosystem services supply in the transnational pilot area. Deliverable of MAREA project. Available at http://marea.balticseaportal.net/outputs/.

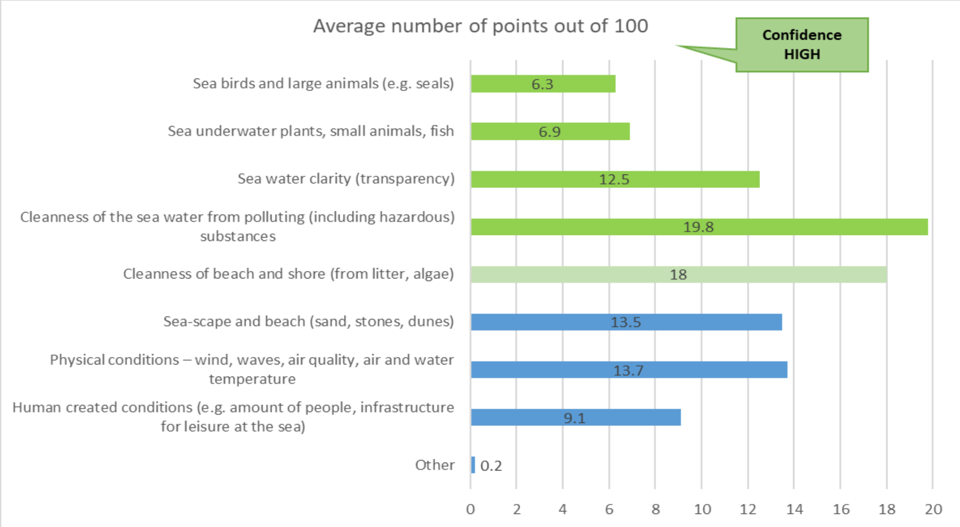
The study developed an index that summarises the features that make coastal areas suitable for the development of cultural and recreational activities. Relevant data layers were combined to produce a coastal suitability index to spatially represent the suitability of Estonian, Latvian and Finnish coastlines for practising different recreational activities (kite-surf, wind-surf, sea-kayaking, swimming, snorkelling, sunbathing). Data layers were used both for defining ideal spatial and temporal frames for practising different recreational activities and calculating the suitability index for each activity. The produced maps (examples are provided below) show the potential of these services in terms of environmental variability (taking into account such environmental variables as wind speed, bottom sediment characteristics, depth, water temperature, daylight hours, distance from the shore) and do not necessarily reflect people's preferences. Preferences are a product of multiple factors e.g. natural conditions, infrastructure, cultural background, etc. which were not taken into account in this modelling exercise.



Box 3. Relative importance of the marine environment characteristics for deriving benefits from cultural ecosystem services (CES) in Latvia.

Information from AKTiiVS (2022) Socioeconomic assessment of marine ecosystem services. Report of the project "Improving knowledge on the state of the marine environment" (No 17-00-F06803-000001). Available at https://www.varam.gov.lv/lv/media/32249/download.

As part of a national survey in 2021 data were collected to assess relative importance of relevant marine characteristics for deriving the benefits from CES, covering all CES. Respondents were asked to allocate 100 points among the listed characteristics according to their importance for deriving the benefits of CES. The results reveal that around 50% of the contribution can be attributed to the biotic characteristics of the marine ecosystem (e.g. linked to marine plants and species, regulating ecosystem services).



Relative importance of the characteristics of the marine environment for deriving benefits of CES according to preferences of the Latvian citizens. (Source: AKTiiVS (2022).) The biotic marine ecosystem characteristics are indicated with green colour bars. The data have been collected from a national survey implemented in 2021 with representative sample. Confidence of the data is high.

The approach for developing the socioeconomic estimates is summarised in Table 23.

Table 23. Approach for developing the socioeconomic estimates for the CES related to recreation. (Source: Own work.)

Assessment elements	Benefits	Corresponding values
Indicators	* No of leisure visits to the sea (per visitor per year). * Share of users (visitors) in the total population.	* Monetary recreational benefits (EUR/year). The benefits cover various CES, values for the individual CES cannot be derived. * Number of jobs (FTE/year) and Added Value (EUR/year) in sectors serving coastal tourism and recreation.
Estimation approach	Data from national surveys in DE, FI and LV. Value transfer for other Baltic Sea countries.	For the monetary indicator: Travel costs method; 'consumer surplus' (CS) EUR per person per year for DE, FI and LV. Value transfer for other Baltic Sea countries. For the AV and employment indicators: Country statistical data.
Data sources	Data from BONUS BalticAPP study for FI, DE and LV (based on national surveys in 2016-2017) (Bertram et al., 2020).	For the monetary indicator: CS per trip from Ahtiainen et al. (2022); number of trips and share of users from Bertram et al (2020); calculated in the current prices using CPI. CS per person per year for DE 182 €, FI 619 € and LV 268 €. For the AV and employment indicators: EUROSTAT data (2019).

The monetary estimate is based on a study, covering Germany, Finland and Latvia (Bertram et al., 2020; Ahtiainen et al., 2022). This study is used since it is the only published recent study, estimating the recreational benefits in relation to the Baltic Sea, based on data for more than one Baltic Sea country. Relevant data from this study are presented in Table 24. The calculated 'consumer surplus' (CS) per person is applied to other Baltic Sea countries using a benefit transfer approach[9].

The used approach involves several assumptions, which impacts the total calculated benefits:

[9] The same approach, which was developed for the costs of degradation analysis for HOLAS III ESA, is used here.

- The study employed two valuation methods – the travel cost method (used in Ahtiainen et al. (2022)) and the contingent behaviour method (used in Bertram et al. (2020)). To follow a conservative approach, the CS estimated by Ahtiaine et al. (2022) is used, which provides lower CS estimates per trip than by Bertram et al. (2020) due to different approaches used for estimating the travel costs and for the econometric modelling.
- CS per person is calculated based on CS per trip, a number of trips per year and a share of users/visitors in total population. Transferring the CS per person estimate to other countries involves assuming a similar number of trips per visitor and a share of users. The available data from surveys in various Baltic Sea countries indicate differences in such data (Table 25). For the number of trips there can be considerable variations across years as indicated by data from Latvia, where national surveys have been conducted regularly (AKTiiVS, 2022). There is not enough data for detailed analysis nor possible value adjustments, accounting differences in the number of trips and share of users. This issue requires further analysis in the future.
- The data are obtained from samples of adult populations, therefore such populations are used also for calculating the total benefits, instead of using the total populations of the countries. The Baltic Sea coastal population is estimated for Russia (5% of the total population).

With the applied assumptions the approach could be seen producing conservative benefit estimates (rather than overestimating them).

Table 24. Data on recreational benefits used for monetary estimation of the benefits of CES related to recreation. (Source: Bertram et al. (2020); Ahtiainen et al. (2022).) The colour denotes confidence (good).

Study countries	Consumer surplus EUR per visit [95% CI] [1]	No of visits per year (SD) [2]	Consumer surplus EUR per visitor per year	Share of visitors in total population [2]	Consumer surplus EUR per person per year (in 2017 prices)
Germany	83.3 [74.2; 92.4]	4.3 (1.0)	358	0.49	176
Finland	79.5 [66.2; 92.9]	10 (3.0)	795	0.76	604
Latvia	66.9 [42.9; 91.0]	4.8 (1.5)	321	0.79	254

[1] From Ahtiainen at al. (2022). [2] From Bertram et al (2020).

Table 25. Share of visitors of the sea for recreation (% of the total population) in the Baltic Sea countries. (Source: Data from various surveys.)

Country	Share of visitors of the sea for leisure as % of the (adult) population (data from representative samples); data collection year in parenthesis
Denmark	74% (2019)[1]
Estonia	75% (2019)[1]; 83% (2022)[2]
Finland	76% (2016)[3]
Germany	49% (2016)[3]; 56% (2019)[1]; 53% (2020)[4]
Latvia	79% (2017); 84% (2019); 83% (2021)[5]
Sweden	62% (2019)[1]; 88% (2020)[6]

[1] Khedr et al. (2023), data from 2019; [2] MAREA Deliverable D.T2.2.2 (upcoming) (http://marea.balticseaportal.net/outputs/), data from 2022; [3] Bertram et al. (2020), data from 2016; [4] Oehlmann et al. (2021), data from 2020; [5] AKTiiVS (2022), data from 2017, 2019, 2021; [6] Nordzell et al. (2020), data from 2020.

The calculated total benefits for the Baltic Sea countries (Table 26) are in range of 34 billion € per year.[10] Comparing this estimate with the similar estimate for HOLAS II (HELCOM, 2018; Czajkowski et al., 2015), which was based on data collected in 2010 covering all the Baltic Sea countries, the benefits are more than two times higher. However, it can still be judged as a conservative estimate, taking into account the developments and changes in the sea use since the survey in 2010.

Table 26. Monetary benefits of CES related to recreation in the Baltic Sea region. (Source: Own calculation.) The colour denotes confidence (moderate-low; good).

	Total (adult) population [1]	Consumer surplus EUR per person per year (in 2020 prices)	Total benefits (million EUR per year)
Denmark	4 373 553	735	3 215
Estonia	997 109	319	318
Finland*	4 147 157	619	2 567
Germany*	62 370 653	182	11 351
Latvia*	1 425 337	268	382
Lithuania	2 096 164	333	698
Poland	28 424 303	297	8 442
Russia [2]	5 403 903	267	1 443
Sweden	7 765 082	686	5 327
Total			**33 743**

Notes. The asterisk marks the study countries from which the values are transferred to other countries. The CS from Finland is transferred to Denmark and Sweden, the CS from Latvia to Estonia, Lithuania, Poland and Russia. The benefit transfer approach is described in HOLAS 3 Thematic Assessment for ESA.

[1] Total population based on data from World Bank (for 2020) (https://api.worldbank.org/v2/en/indicator/SP.POP.TOTL?downloadformat=excel); adult population is accounted (estimated to be 75% of the total population).

[2] The Baltic Sea coastal population is assumed to be 5% of the total population of Russia.

The developed estimate covers various CES, and the monetary estimation approach does not allow estimating the benefits of individual CES. It can be assumed that the estimate covers C1-C6, however benefits of some CES might be covered only partly by such an estimation approach (for instance, C3 Environment for science and education, C4 Environment for maintenance of cultural and historical heritage). Additional data on relative importance of the individual CES are provided in next sub-section.

Table 27 provides data for the ES indicators on added value and employment, which covers coastal tourism accommodation sector. There are other sectors also that benefit from the recreational activities, however there is no a common approach in the Baltic Sea countries for considering these other sectors, therefore they are not assessed.

[10] If using total populations of the countries instead of the adult populations, the calculated benefits are 45 billion € per year.

Table 27. Data on the added value and employment indicators for the CES related to recreation, covering coastal tourism accommodation sector. (Source: EUROSTAT data for 2019.) The colour denotes confidence (high).

Country	Annual value added at factor cost from coastal tourism accommodation sector (million €)	Number of persons employed in coastal tourism accommodation (thousand FTE*)
Denmark	907.2	12.7
Estonia	111.5	4.7
Finland	200.5	3.5
Germany	3302.7	76.6
Latvia	85.0	4.4
Lithuania	37.2	1.8
Poland	451.3	15.5
Russia	no data	no data
Sweden	1455.8	24.0
Total	**6551.2**	**143.3**

* Full-time equivalent.

C7 Existence of marine habitats and species

This CES aims to cover non-use value of the marine habitats and species – the benefits for human well-being from preservation for future generations and existence of the habitats and species, independently on the use of the ecosystem. There are monetary valuation approaches that allow measuring marginal changes in these benefits, but not the total benefits as such. Therefore, other socioeconomic data are used for illustrating the benefits from this CES.

Figure 5 provides data on relative importance of C7 comparing to other CES. The data come from three Baltic Sea countries, representing diversity of socio-ecological contexts in the sea region. The data have been obtained from national surveys in each country conducted in 2016-2017, based on representative national samples (Ahtiainen et al., 2019). The results reveal that the importance of the existence of marine habitats and species is assessed by Germans and Finns as high as the importance of the recreational and aesthetic experiences, while the importance of the existence value is lower in Latvia (11 points on average out of 100). At the same time, there are data indicating changes in the societal preferences towards higher importance of the existence value (see Box 4).

While the recreational benefits are estimated to be in range of 34 billion € per year, these results reveal that also the existence of marine habitats and species brings considerable benefits to human well-being.

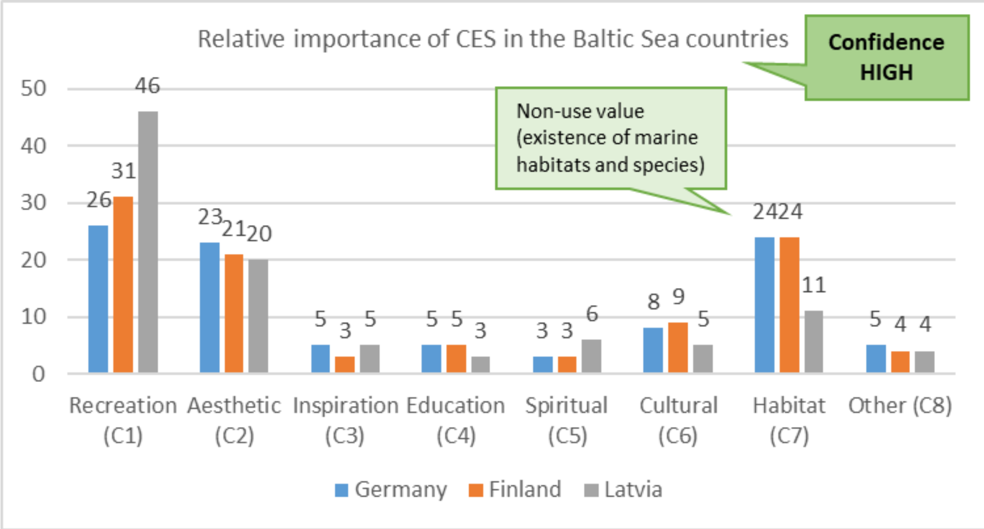
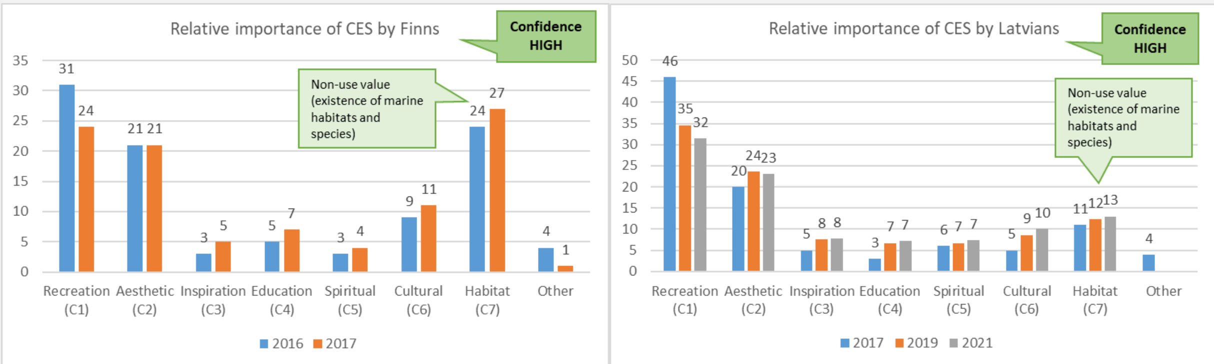


Figure 5. Relative importance of the cultural ES (average points out of 100 allocated to each CES) for the Baltic Sea countries – Germany, Finland, Latvia. (Source: Ahtiainen et al. (2019).) The data have been collected from national surveys with representative samples, implemented in 2016-2017. Confidence of the data is high, since these data are derived directly from national representative surveys.

Box 4. Changes in the importance of the benefits from the existence of marine habitats and species based on preferences of Finnish and Latvian citizens. (Source: Based on data from Ahtiainen et al. (2019), Nieminen et al. (2019) and AKTiiVS (2022).)

The data are taken from national surveys in Finland and Latvia, where respondents have been asked to assess relative importance of the benefits from CES by allocating 100 points among the individual benefits of CES. Such data are available for Finland from two surveys (in 2016 and 2017) and Latvia from there surveys (in 2017, 2019 and 2021) allowing comparison of the results. The results reveal decreasing relative importance of recreational experiences and increasing importance of the existence of marine habitats and species, as well as the CES related to intellectual and spiritual interactions with the marine environment. In particular, the results for Latvia, where data from three surveys are available, demonstrate changes in societal preferences towards increasing recognition of diverse values provided by the marine ecosystem as well as importance of the existence and bequest value of the marine habitats and species.



Relative importance of the cultural ES (average points out of 100 allocated to each CES) based on the assessment of Finish citizens (left chart) and Latvian citizens (right chart). (Source: Based on data from Ahtiainen et al. (2019), Nieminen et al. (2019) and AKTiiVS (2022).) The data have been collected from national surveys with representative samples. Confidence of the data is high.

4.3. Illustrations on non-monetary indicators for the socioeconomic assessment of the marine ecosystem services

Other (non-monetary) socioeconomic indicators can be used for broader assessment of the human well-being aspects. They can provide additional information, for instance, on spatial dimension of the ES benefits and societal preferences. Such indicators, in most cases, require special data collections (surveys), and no uniform data are available for all the sea region countries. Therefore, only country-scale illustrations could be provided based on available data. Some examples are provided further in this chapter.

4.3.1. Most often visited sites for leisure at the sea

Figure 6 shows most often visited sites by Germans, Finns and Latvians for leisure at the sea (Bertram et al., 2020). The data were collected from national surveys in each country (in 2016-2017) using participatory GIS method, where respondents were asked to mark on a map their most often visited sites for leisure at the sea. Such GIS data can be used, for instance, for mapping areas with different intensities of recreation to support spatial planning policies.

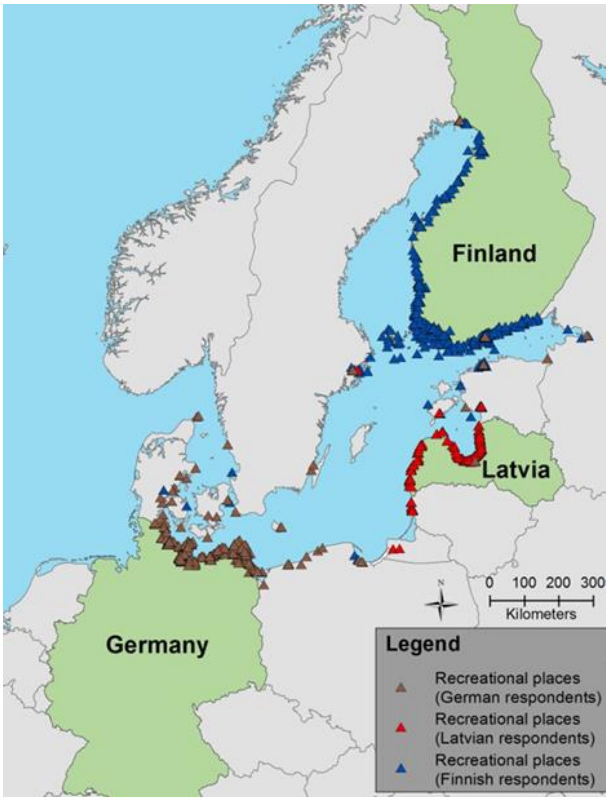


Figure 6. Illustration on mapping coastal recreational sites – the most often visited sites by Germans, Finns and Latvians for leisure at the sea. (Source: Bertram et al. (2020).) GIS data were collected from national surveys (in 2016-2017) based on representative samples. Confidence of the data is high.

4.3.2. Benefiting population of the marine ecosystem services

Figure 7 illustrates an assessment of benefiting population of all relevant marine ES based on data from Latvia, which have been collected from a national survey implemented in 2019 (AKTiiVS, 2022). Respondents were provided information about the marine ES and their benefits to humans and were asked to assess importance of the benefits of each ES with 10-point scale, where zero means that the benefit is not important at all, 5 means that the benefit is of moderate importance and 10 means that the benefit is highly important. Respondents who marked 6 to 10 points are accounted as the benefiting population of that ES, and their number is calculated as a share of the whole sample. Since the data have been collected from a representative sample (N=701), the results are generalised to the whole national population, providing evidence on the benefiting population based on the citizens' preferences.

The results reveal that the regulating ES are the most highly assessed group of ES overall where the benefiting population is estimated to be 87% (82-97%) for nutrient regulation, 94% (90-99%) for hazardous substances regulation and 95% (93-99%) for carbon sequestration respectively.[11] The benefits from recreational and aesthetic experiences were assessed as important by 92% (88-98%) and 91% (87-97%) of respondents respectively, and this share is higher than the regular users of the sea for recreation – 84% of the national population based on data from the same survey[12]. This result indicates that these ES has also non-use value (e.g. option use and/or be-quest value). Worth noting also the considerable share of the benefiting population for the existence of marine habitats and species – 81% (74-93%) of the total population.

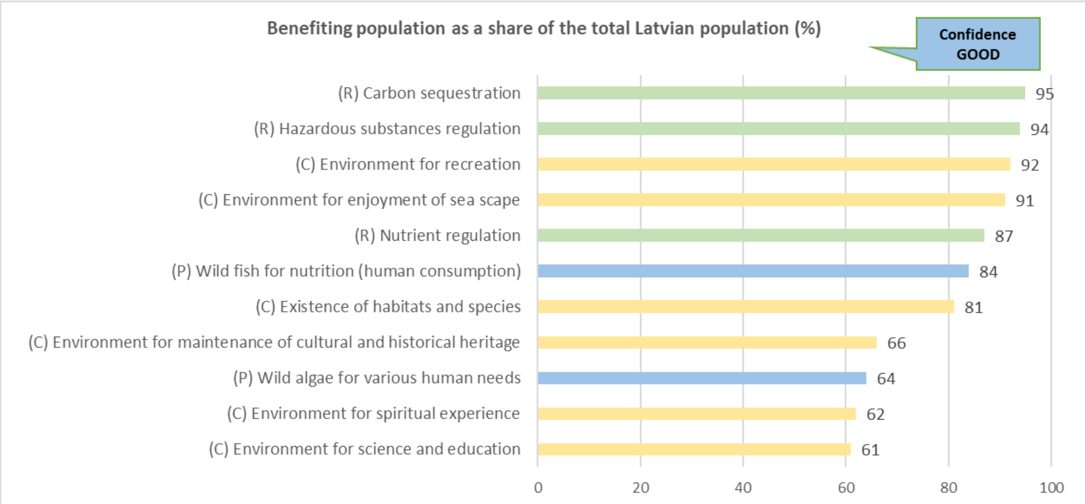


Figure 7. Illustration on benefiting population for the marine ecosystem services based on data from Latvia. (Source: AKTiiVS (2022).) The benefiting population is estimated as a share of the total national population (%). The data have been collected from a national survey implemented in 2019 with representative sample (n=701). The colours denote ES of different groups – provisioning (blue), regulating (green) and cultural (yellow) ES. Confidence of the estimates is good, since they are based on data derived directly from a national representative survey.

4.3.3. Relative importance of the marine ecosystem services

Figure 8 provides an illustration on relative importance of benefits, covering all relevant marine ecosystem services, based on data from Latvia, which have been collected from a national survey implemented in 2019 (AKTiiVS, 2022). Respondents were asked to distribute 100 points among the benefits of marine ecosystem services according to their importance. The results reveal that about one third of the points (33 points) overall is allocated to the benefits of provisioning ES (wild fish and algae for various human needs) and only 24 points overall to the benefits of cultural ES with considerable importance of the benefits from existence of marine habitats and species (8 points out of 100). The highest importance is allocated overall to the benefits of regulating ES (hazardous substances regulation, carbon sequestration and nutrient regulation) with 43 points out of 100 in total.

[11] The intervals are calculated applying alternative assumptions on what respondents should be accounted as the beneficiaries – those who marked at least 7 points (conservative assumption) for the lower bound of the share and those who marked at least 5 points for the upper bound.

[12] Those respondents who visited the sea for leisure at least once within the last three years.

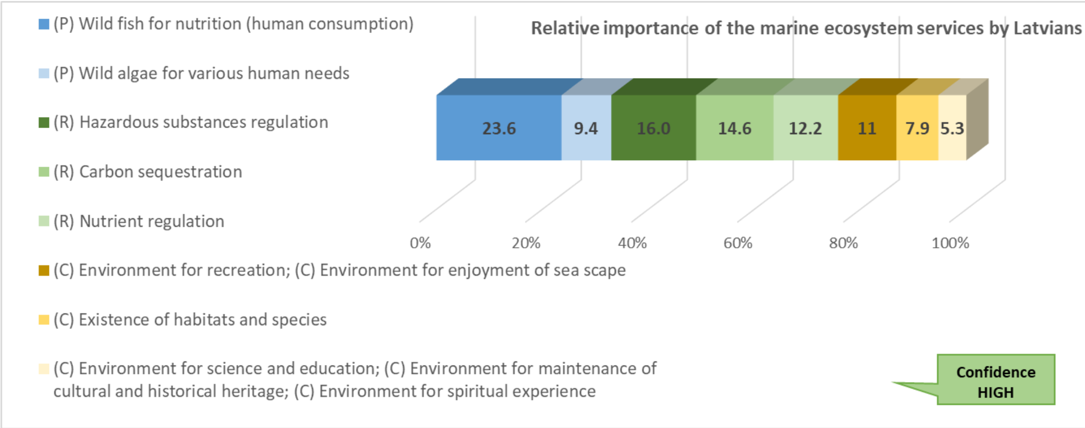


Figure 8. Illustration on relative importance of benefits from the marine ecosystem services (average points out of 100 allocated to the benefits of each ecosystem service) based on the assessment of Latvian citizens. (Source: Based on data from AKTiiVS (2022).) The data have been collected from a national survey implemented in 2019 with representative sample. Confidence of the data is high.

These results suggest that the benefits of regulating ES are higher than monetised in the current assessment, in particular for carbon sequestration ES. The results also indicate that benefits from hazardous substances regulation ES, which are not estimated in the current assessment, could be at least as high as the estimated monetary benefits of nutrient regulation ES. It should be noted however, that such conclusions have moderate confidence, since they are based on data from one Baltic Sea country only.

4.4. Assessing well-being impacts of policies for preserving the marine ecosystem services

The ES assessment aims to support the policy making in relation to the protection and management of the marine environment. It can be supported by assessing the socioeconomic implications of policy scenarios related to, for instance, implementing (or not implementing) measures for improving state of the marine environment. The changes in the ecosystem created by scenarios can be assessed in terms of changes in the ES supply. The socioeconomic assessment is needed to assess the **impacts of these changes on human well-being**.

The developed indicators' approach can serve a possible approach for assessing the socioeconomic impacts. If changes in the ecosystem components and the resulting changes in the ES provision are assessed, the corresponding changes in the benefits and values, measured by indicators, can be estimated. There are methodological issues to be considered for such assessment. For the monetary estimation they include, for instance, aggregation of the benefits of individual ES derived from different monetary assessment methods, non-linearity of marginal benefits. But it serves a simple approach based on available data.

Another approach is to base the socioeconomic estimates on valuation studies applying sound monetary valuation concepts and methods. However, conducting such studies require considerable resources, while using available studies requires adjusting their values to the policy context, which increases the uncertainty.

The current information base for the sea region is not sufficient to assess the socioeconomic impacts of relevant policy scenarios based on the ES approach. The gaps relate to both the assessment of the ES supply as well as the estimation of the benefits. The work aimed to provide illustrations on how the assessments based on the ES approach can support various policy needs. The illustrations focus on monetary estimation of (changes in) ES values, which provides a common metric, but also is determined by information availability.

Illustrations on assessing well-being impacts of policies by applying the ES approach

The developed illustrations are summarised in Table 28. They demonstrate various policy purposes and contexts that can be served by such assessments, for instance, types of the policy assessments (e.g. cost of degradation due to a specific pressure or benefits of a policy measure), types of benefits (e.g. recreational benefits) and assessment scales (e.g. local impacted areas, national marine waters or sea region).

Table 28. Illustrations on assessing well-being impacts of policies by applying the ES approach. (Source: Own work.)

Illustration (references)	Pressures and/or measures	Habitats	Ecosystem services	Scale	Monetary estimation approach	Estimates
(1) Changes in recreational benefits from improved state of the marine environment (Ahtiainen et al., 2022; Bertram et al., 2020)	Various pressures affecting the environmental quality for recreation (not specified)	Various habitats contributing to the environmental quality for recreation (not specified)	Cultural ES related to recreation	Baltic Sea	A monetary valuation study, applying a contingent behaviour method, and a benefit transfer	Changes in 'consumer surplus' based on changes in recreational trips for improved state of the marine environment. Changes in the total recreational benefits for the Baltic Sea.
(2) Cost of degradation based on foregone benefits from changes in the ES supply (Armoškaite et al., 2021; AKTiiVS, 2022)	Negative impact of invasive marine species (round goby)	Benthic habitats impacted by the given pressure	All ES provided by the benthic habitats	Local marine areas (in the Latvian marine waters)	An indicators' approach, using monetary indicators based on various estimation methods for individual ES	Changes in habitat structure and resulting changes (positive and negative) in supply of individual ES. Monetized (foregone) benefits for the Latvian citizens due to the changes in the ES supply.
(3) Well-being impacts from improved state of ES due to designation of new marine protected areas (MPAs) (Pakalniete et al., 2021; AKTiiVS, 2022)	Impact of a policy measure – designation of new offshore MPAs (various MPA size scenarios)	Benthic hard bottom (reef) habitats aimed to be protected by the MPAs	All ES provided by the reef habitats	National (Latvian) marine waters	A monetary valuation study, applying a choice experiment method	Supply level and state of ES in various new MPA size scenarios. Resulting changes in the ES benefits for the Latvian population.

(1) A sea region scale illustration on changes in the recreational benefits from improved state of the marine environment

This illustration (Box 5) provides a sea region scale assessment on changes in recreational benefits from improved state of the marine environment. The estimates are based on a valuation study, applying a contingent behaviour method, in three countries of the Baltic Sea (Germany, Finland and Latvia) and benefit transfer for deriving estimates for other countries. The result includes estimated changes in 'consumer surplus' per person per year, which is multiplied by the population in each country to calculate the total changes in the recreational benefits. An advantage of this assessment relates to the use of sound monetary valuation approach, while limitations relate to linking these results to specific policy scenarios.

Box 5. A sea region scale illustration on changes in the recreational benefits from improved state of the marine environment. (Source: Based on data in Ahtiainen et al. (2022) and Bertram et al. (2020).)

A valuation study, implemented in three Baltic Sea countries (Germany, Finland and Latvia) in 2016-2017, provides estimates on changes in the recreational benefits for possible future scenarios of the state of the marine environment. The environmental quality is characterised in scenarios using such attributes as water clarity, appearance of blue-green algal blooms, amount of algae washed ashore and number of bird and plant species. The recreational benefits are estimated based on travel costs collected as part of the study. Respondents were asked to assess the current state according to their perceptions and to state a number of their recreational trips to the sea for various future scenarios, which were characterised by various levels of the environmental attributes. The results allowed calculating changes in the benefits ('consumer surplus' per person per year) for various environmental quality scenarios. A benefit transfer approach is used to derive estimates for all Baltic Sea countries. The calculated changes in the total recreational benefits comparing the best environmental case scenario to the current state are in range of 9.5 billion EUR per year for the whole Baltic Sea region.

Description of the environmental attributes and their levels for the survey (Bertram et al., 2020).

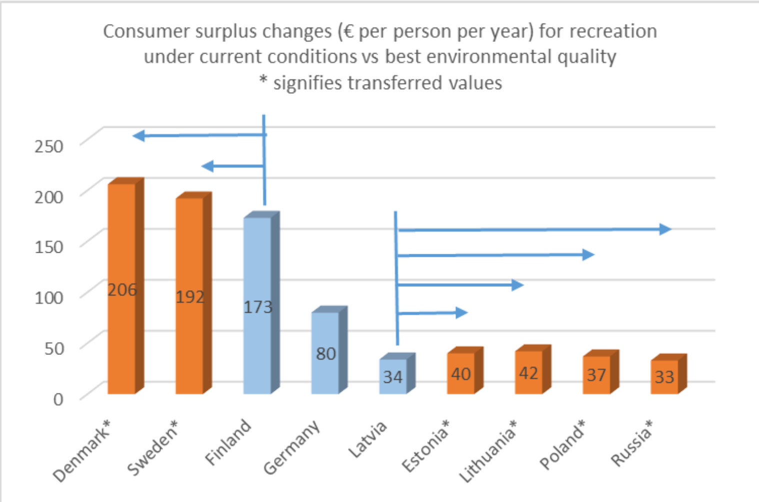
Attribute	Description	Levels
Water clarity	Water clarity indicates how deep you can see under the surface.	Turbid (0), somewhat turbid (1), somewhat clear (2), clear (3)
Appearance of blue-green algal blooms	Blue-green algae are a special type of algae that can grow intensively in the water column during the summer and can form a visible thick mat/layer on the surface of the water at some parts of the sea	Often (3), sometimes (2), seldom (1), never (0)
Amount of algae on shore	Some algae such as different typed of seaweed can be washed ashore to varying amounts and can also produce unpleasant odours during they decay	Often (3), sometimes (2), seldom (1), never (0)
Number of bird and plan species	A healthy ecosystem supports a large diversity of native species, including healthy populations of sea birds, plants and fish	Low (0), rather low (1), rather high (2), high (3)

Attribute levels in the current conditions, according to perceptions of respondents, and the valued best case scenario (Bertram et al., 2020). For blue green algal blooms and algae onshore, higher values indicate worse conditions.

Attributes	Average perception of the current quality (median/mean)			Best case scenarios
	Germany	Finland	Latvia	
Water clarity	2 (somewhat clear) /2.07	1 (somewhat turbid) /1.30	2 (somewhat clear) /1.70	3 (clear)
Blue green algal blooms	1 (seldom) /0.98	1 (seldom) /1.44	1 (seldom) /1.31	0 (never)
Algae onshore	1 (seldom) /1.25	2 (sometimes) /1.55	2 (sometimes) /1.63	0 (never)
Bird and plant diversity	2 (rather high) /1.90	2 (rather high) /1.53	2 (rather high) /1.47	3 (high)

Calculated changes in the recreational benefits **million EUR per year** (based on data in Ahtiainen et al. (2022) and Bertram et al. (2020)). Total benefits are calculated using adult populations of countries, 5% of the total population of Russia.

Denmark	901
Estonia	40
Finland	717
Germany	4990
Latvia	48
Lithuania	88
Poland	1052
Russia	178
Sweden	1491
Total	**9505**



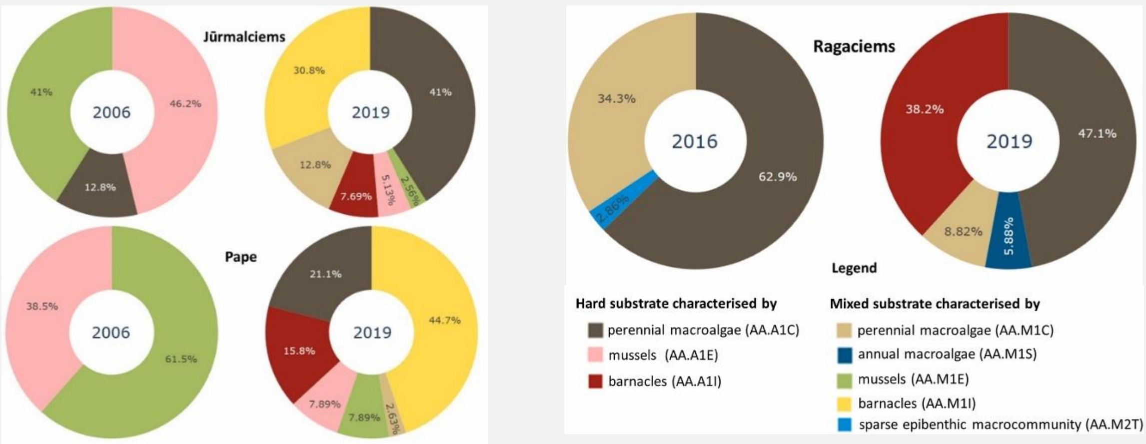
(2) An illustration on using the ecosystem services approach for assessing cost of degradation due to an impact of invasive species (round goby)

This illustration (Box 6) provides an assessment of cost of degradation of the marine environment due to pressures on marine habitats – the pressure of non-indigenous species. The cost of degradation has been assessed based on foregone benefits for society due to reduced supply of ES. This example illustrates complexity of the ES assessment, when pressure creates changes in habitat composition, leading to different changes (positive and negative) in supply of individual ES. The ES supply assessment allows indicating these changes, but the monetary valuation is needed to assess the net impact for society. The net well-being impact has been estimated in monetary terms, using various estimation methods for the individual ES.

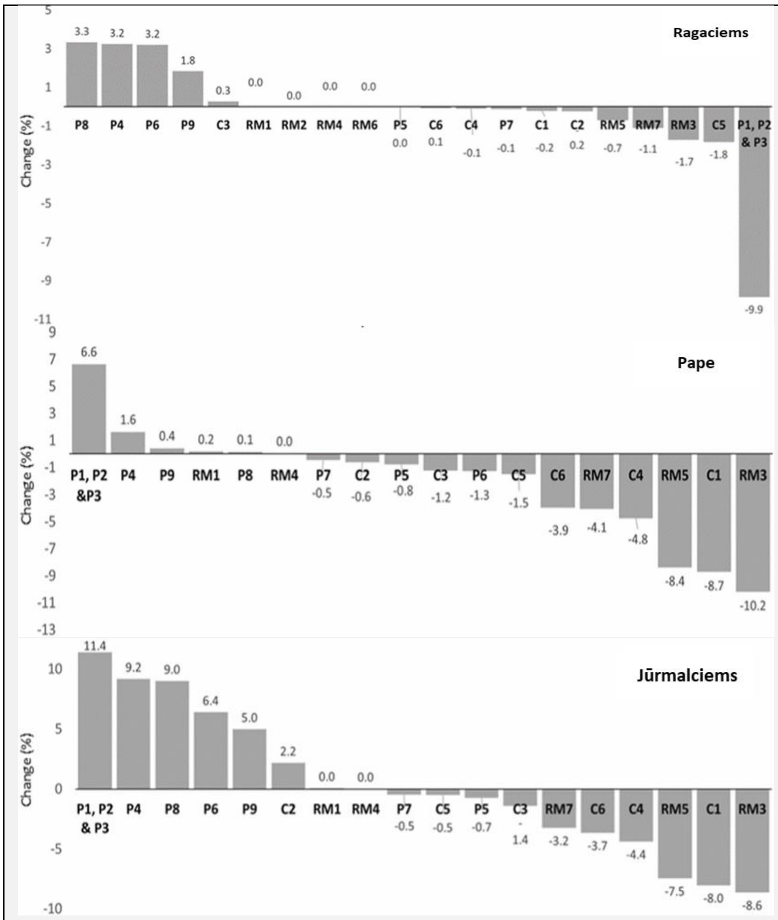
Box 6. An illustration on using the ecosystem services approach for assessing cost of degradation due to an impact of invasive species (round goby). (Source: Based on information in Armoškaite et al. (2021) and AKTiiVS (2022).)

The study analysed changes in habitat composition and resulting changes in ES due to an impact of round goby (the most important invasive species in the Latvian marine waters) in three local marine sites (Jūrmalciems, Pape and Ragaciems, each occupying around 10 km^2). Changes in the habitat composition were assessed based on monitoring data for two periods. The ES supply was assessed by applying an ES assessment tool, developed for the Latvian marine waters (Armoškaite et al., 2020). Changes in the ES supply indicate an increase in many provisioning ES and decrease in some cultural ES and regulating ES. The well-being impacts of the changes in the ES supply were assessed in monetary terms by estimating the ES benefits for each ES supply level and calculating difference between the two scenarios. The monetary ES benefits are estimated, using various methods for individual ES (e.g. market prices of fish products, replacement costs for nutrient regulation ES, 'social costs of carbon' for carbon sequestration ES, travel costs for ES related to recreation). The foregone benefits from the ES is estimated in range of 0.86 million EUR per year for all sites, and the majority of these costs relate to loss of regulating ES (AKTiiVS, 2022).

Change in benthic habitat composition in the study sites (Armoškaite et al., 2021). Habitats are classified according to the HELCOM Underwater biotope and habitat classification system (codes are indicated in parenthesis).



Changes in the ES supply (%) in the study sites Ragaciems, Pape and Jūrmalciems, assessed by applying the ES assessment tool for the Latvian marine waters (Armoškaite et al., 2020). P denotes provisioning ES, R – regulating and C – cultural ES. More details in Armoškaite et al. (2021).



(3) An illustration on assessing national ES benefits from a policy measure – designation of new offshore marine protected areas (MPAs)

This illustration (Box 7) provides an assessment of national benefits from protecting marine habitats by designation of new offshore marine protected areas (MPAs). The study analysed various scenarios with differing size of potential new offshore MPAs for protecting benthic hard bottom (reef) habitats in the Latvian marine waters. The scenarios have been characterised in terms of supply level and state of relevant ES, and they have been valued by applying a choice experiment method. The assessment is based on a specially designed economic valuation study, thus illustrating this approach for assessing changes in the ES benefits from a policy measure – designation of new MPAs.

Box 7. An illustration on assessing the ecosystem service benefits from designation of new offshore marine protected areas (MPAs). (Source: Based on information in Pakalniete et al. (2021) and AKTiiVS (2022).)

The study analysed possible future scenarios of the sea use and different size of potential new (offshore) MPAs for protecting benthic hard bottom (reef) habitats in the Latvian marine waters. The scenarios have been characterised in terms of supply level of the marine ES, which was assessed by applying an ES assessment tool, developed for the Latvian marine waters (Armoškaite et al., 2020). These scenarios have been applied in a valuation study, using a choice experiment method, which was implemented in 2019, based on a representative national sample.

The study provides estimates on the mean WTP per person per year for the state of ES in each policy scenario (comparing with the business-as-usual scenario). These estimates have been multiplied by the (adult) national population to calculate the national benefits. The results reveal benefits for the Latvian society from improving state of the ES in range of 8.6 million EUR (5.7-11.6 million EUR 95% CI) in the moderate policy scenario and 8.9 million EUR (5.8-12 million EUR 95% CI) in the maximum policy scenario (AKTiiVS, 2022).

Supply of the ES (ratio), depending on the protection extent of various reef habitat types (Pakalniete et al., 2021).

The protection extent characterises the share of the habitat area that is highly protected and, hence, preserved (concerning the macroalgae habitats, the mussel habitats or all the reef habitat types in the estimates (1), (2) and (3) respectively). The ES ratio (in cells) is calculated as the mean ratio for all ES provided by the reef habitats (14 ES). Colours depict scenarios that formed basis for the economic valuation (the business as usual scenario marked with blue and the policy scenarios with different size of offshore MPAs marked with green).

Estimates with changing area for various reef habitat types	**Preserved habitat area by establishing MPAs as a share (%) of the total habitat area**										
	100%	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**	**30%**	**20%**	**10%**	**0%**
(1) with changing area of macroalgae habitats only, 100% area for the other reef habitat types	1.00	0.96	0.91	0.87	0.82	0.78	0.74	0.69	0.65	0.61	0.56
(2) with changing area of mussel habitats only, 100% area for the other reef habitat types	1.00	0.95	0.90	0.85	0.80	0.75	0.71	0.66	0.61	0.56	0.51
(3) with equal changing in areas of all reef habitat types	1.00	0.90	0.80	0.70	0.60	0.50	0.40	0.30	0.20	0.10	0.00

Willingness-to-pay EUR per person per year for changes in the state of ecosystem services (ES) provided by the reef habitats, comparing the policy scenarios against the business-as-usual scenario state (Pakalniete et al., 2022).

Attributes related to the marine ecosystem services	**Mean WTP EUR per person per year**	**95% Confidence Interval (CI)**
State of ES provided by macro-algae habitats: rather good	2.74	1.8; 3.67
State of ES provided by macro-algae habitats: very good	2.88	1.87; 3.88
State of ES provided by mussel habitats: rather good	2.94	1.94; 3.95
State of ES provided by mussel habitats: very good	2.98	1.95; 4.02

5. Conclusions and recommendations for the future work

The updated HELCOM Baltic Sea Action Plan (HELCOM, 2021) includes actions on integrating the economic and social analyses in HELCOM work strands to allow for assessment of the linkages between the marine environment and human wellbeing (HT15), on further development and application regionally coordinated methods in support of analyses of ES and providing an initial demonstration of how they can be used in policy development (HT18), and on improving the use of results from economic and social analyses in decision-making, including through establishing a set of indicators that describe the economic and social aspects of the marine environment (HT16). This ES assessment developed as part of BLUES project contributes to implementation of these actions. The ACTION-BLUES conceptual framework was further developed to integrate the ES approach for more explicit linking the marine environment and human well-being and assessing the well-being impacts of policies for protection and sustainable use of the marine environment. The conducted work included also developing a sea region scale approach and assessments for quantitative and monetary estimation of the ES benefits and socioeconomic values, as well as providing an initial demonstration on how such socioeconomic assessments can be used in policy development. The current information base for the sea region is not yet sufficient for fully implementing the developed framework. It would require assessing changes in the ecosystem in sea use and/or policy scenarios and resulting changes in the ES supply. These changes could then be assessed in terms of the impacts on human well-being, based on changes in the ES benefits and values. The gaps relate to both the assessment of ES supply as well as the assessment of benefits and socioeconomic values.

The developed assessment provides advancement towards quantified assessment of the link between the ecosystem and human well-being. However, many methodological and information gaps remain to make such assessment as a policy support tool. There is a need to further develop quantitative estimates on the ES supply to cover all relevant ecosystem components, as well as approach and estimates for linking the ecosystem components to the supply of provisioning and cultural ES. Quantified linkages are needed for assessing changes in the ES supply and socioeconomic values in the sea use and policy scenarios.

With regards to the socioeconomic assessments, the needs for the future work relate to further development of the socioeconomic ES assessment methods and information base, as well as analytical capacity for policy scenario and trade-off analysis.

As demonstrated by the current assessment, the socioeconomic ES estimates are based on various valuation methods, providing different estimates for individual ES (e.g. market value, avoided costs, consumer surplus). This situation is largely determined by information availability. However, improvements in the methods need to be explored to guide the future research and data collection efforts. In addition, specific methodological issues need to be addressed, for instance, aggregating socioeconomic estimates for various ES, spatial and trade-off analysis of the ES benefits and values. Also, more advanced approaches for assessing uncertainties need to be considered.

Confidence assessment of the developed estimates indicates rather high uncertainties – the confidence has been assessed as moderate for the majority of the sea region estimates (except for the value added and employment data). The main reason is the lack of consistent data from the countries. The assessment needs diverse data, which, in most cases, come from specially conducted national surveys. International research projects form an important source of consistent data. But also national studies can advance the methodological and information base for the sea region assessment. Further efforts should be targeted to developing quantitative and monetary approaches and estimates, including for the ES, which are not covered by the current assessment (in particular, the hazardous substances regulation). Further work on the sea region scale should include specifying the data needs, promoting the data collections and supporting reviews and synthesis of the information base.

In order to support the policy making in relation to the protection and management of the marine environment, there is a need to analyse the socioeconomic implications of environmental protection and sea use policy scenarios. The changes in the ecosystem created by scenarios can be assessed in terms of changes in the ES supply. The socioeconomic assessment is needed to assess the impacts of these changes on human well-being. Such a complex assessment needs information and analytical tools, which are currently missing in particular for the socio-economic analysis. Development of such tools is an important future work to improve the analytical capacity for the policy scenario and trade-off analysis.

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