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Development methods for assessment and mapping of ecosystem services of marine and inland waters

REPORT

Summary

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Introduction

The general purpose of the project "Development methods for assessment and mapping of ecosystem services of marine and inland waters" is to help stop the decrease of biodiversity in water bodies and damaging of ecosystems in the European Union by supporting the preservation and restoration of ecosystems and their services in Estonia. The last decade has given rise to an understanding in the environmental policies that ecosystem degradation and loss of biodiversity can be better explained to households, enterprises and the public sector by describing these phenomena as units offering economical goods and services that directly or indirectly serve people's needs. Such goods are now called ecosystem services. In the context of economical terminology, ecosystem services can be considered as:

- goods or ecosystem products such as berries, mushrooms, wood, herbs, drinking water, etc.;
- services or tourism and recreational possibilities, ecological, ecological regulatory functions such as water treatment, climate regulation, habitats, waste degradation, etc.;
- cultural values or spiritual and religious experiences, cultural heritage, study and research possibilities etc.

Three better known systems developed in MEA (2005), TEEB (2008) and CICES (2013) projects are used for the classification of ecosystem services. All the aforementioned systems classify direct ecosystem services or services ready to be directly used by society to increase its well-being as (1) provisioning services, (2) regulating and maintenance services, and (3) cultural services. In addition to direct services, MEA and TEEB observe indirect services, classifying them accordingly as support services or habitat services. As ecosystem services are determined and classified with the aim of assessing their economic value, only direct services must be taken into consideration in order to avoid double counting, and this should be done using only the CICES classification that allocates services into three ecosystem service classes.

The following tasks were set to fulfil the abovementioned general purpose of the project:

1. Develop methods for determining services of aquatic ecosystems, including
   1.1. methods for determining services of river ecosystems;
   1.2. methods for determining services of lake ecosystems;
   1.3. methods for determining services of coastal waters ecosystems.
2. Compile a list of indicators of river, lake, and coastal water ecosystem services.
3. Produce an overview of methods for mapping ecosystem services.
4. Conduct research for determining the economic value of the ecosystem services of chosen pilot waters and draw up recommendations for implementing indirect assessment methods.

In order to check the methods developed within the framework of the project, pilot waters were chosen based on the accessibility of data, geographical location, condition, pressures, type, size, usage, and number of waterbodies. Chosen pilot areas are Pärnu Bay, Haapsalu Bay and Tallinn Bay; the River Väike Emajõgi, the Pirita River and the Pärnu River; and Lake Pühajärv (in Valga County), Lake Harku and the Kurtna Lake District (Lake Valgejärv, Lake Konsu, Lake Kuradijärv).

Determining and assessing of services of aquatic ecosystems begins with the assessment of potential services, i.e. a preliminary assessment (Figure 1, section I). The initial ecosystem service supply is assessed according to the methodology developed in this project and described below. In order to

specify the supply of ecosystem services (Figure 1, section II), it is necessary to determine the current status. For that, specific numerical values of indicators developed during the course of the project are used. The indicators are developed according to the DPSIR model (defined in Chapter 4). On the basis of this model, it is possible to bring out and present three-dimensionally the positive or negative co-effects resulting from the overlapping of the demand, pressure, provision, consumption, and maintenance or restoration of the service. Such assessment of ecosystem services is described in the chapter on the methods for assessing ecosystem services of coastal seas. It is possible to determine the economic value of the services (Figure 1, section III) by using the ecosystem assessments and maps found in sections I and II.

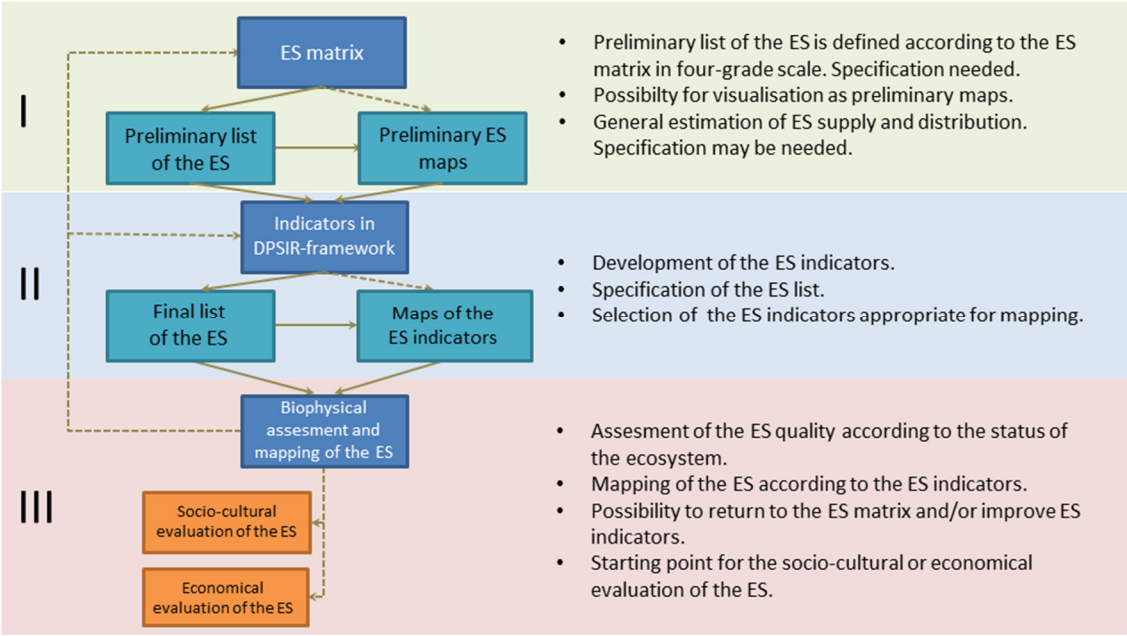


Figure 1. The performance process diagram of methodology of ecosystem services evaluation and mapping.

1. Methods for determining river ecosystem services

The methodology for determining and assessing river ecosystem services is based on the assumption that the supply of river ecosystem services depends on the condition of the river. The river is seen here from a geomorphological aspect as a currently functioning ecosystem formed within the bed of the watercourse. In the interest of accuracy, when determining ecosystem services it is recommended to assess rivers by water bodies, whereas the latter term is defined in the 28.07.2009 Regulation No. 44 of the Minister of the Environment (RTL 2009, 64, 941). Also resulting from this regulation is the concept of the ecological and chemical status of water body. The ecological status of water body can be bad, poor, moderate, good, or high, and its chemical status can be poor or good. (See Table 1, columns 3 and 4.) The presence of fish stock is one of the most well-known and understandable ecosystem services of water bodies and is added to the methodology in the case where the ecological status of the water body is considered moderate.

Table 1. Assessments of status classes and supply of ecosystem services of water bodies in colour

Status class				Ecosystem service supply
Hydro-morphological	Morphological	Ecological	Chemical	
1.	2.	3.	4.	5.
very strong human impact	small (MOI*<0,8)	bad	poor	0 - no supply
strong human impact		poor		1 - insignificant supply
moderate human impact	average (MOI=0,8-3),	moderate		2- moderate supply
small human impact		good		3 - significant supply
natural	large (MOI>3)	high	good	4 - very significant supply

*morphology index. Calculated with formula (2)

The assessment of the hydro-morphological status of rivers makes use of the hydro-morphological aggregate index (HMI) that in Estonia reflects the possible effect of pressures on watercourses and is calculated on the basis of drainage, obstructions in the riverbed, water abstraction, wastewater disposal, meanders, land cover of riparian zones and its relation to the emergence of floodplains. The HMI values have been calculated for 300 water bodies in Estonia (Loigu *et al*, 2014). The hydro-morphological status classes stem from the HMI values, and the assessment scale can be found in the first column of Table 1.

A list of direct ecosystem services of rivers can be found in Table 2.

Table 2. List of river ecosystem services (P - provisioning, R - regulating and maintaining, C - cultural and Ab - abiotic services)

Service group	Service	Explanation
P	Fish stock (commercial fishing)	According to the Ministry of Agriculture, 22 rivers were used for professional fishing in 2015. Leisure fishing is part of cultural services.
P	Surface water supply (drinking water)	Depending on the ecological and chemical status of the water and its supply, it is assumed that the water of Estonian watercourses can be used for drinking water.
P	Water for shellfish and fish farming (in aquaculture)	
P	Water for industrial and agricultural use	For example, cooling, irrigation and rinse water.
R	Habitat maintenance	The biodiversity of habitats in a water body is considered.
R	Preservation of protected and key species	Rivers or parts of rivers providing habitats for wild salmonids and shellfish are differentiated according to the data of the environmental register.

R	Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	No significant human impact on the water body is detected.
R	Maintenance of hydrodynamics and flood protection	It is better if there is no significant human impact on the hydro-morphological parameters of the watercourse (barrages etc.).
C	Environmental conditions suitable for recreation (by type)	Different recreational activities (i.e. hiking, rowing, swimming, etc.).
C	Environmental conditions suitable for leisure fishing and hunting (by type)	Depending on the type of fish, the stock and fishing possibilities are assessed.
C	Opportunity for research	The characteristics of the watercourse are assessed as well as the potential for conducting research.
C	Opportunity for education	Conditions suitable for outdoor study.
C	Source of inspiration for creative activity	Assessing the service is very subjective since creative activity is stimulated by very different aspects.
C	Natural symbols (spiritual sites, national symbols)	National symbols, sacred places acknowledged by society.
Ab	Hydropower	Structures producing hydropower (barrages, power plants).
Ab	Transport (shipping and ice roads)	Navigation (navigable rivers) or winter transport (official ice road). Ice skating is part of cultural services.

The potential of river ecosystem services is assessed on the basis hydro-morphological, ecological and chemical statuses on a five point scale as shown in column 5 of Table 1.

Depending on the hydro-morphological, ecological and chemical status of the river, the matrix in Appendix 1 can be used for assessing the potential of river ecosystem services. The assessments included in the fields of the matrix about the potential supply of ecosystem services come from river experts and have been verified on the basis of pilot areas both by means of focus group interviews and specific numeric values of existing indicators. The assessments can be mapped and provide an initial overview of ecosystem services of a water body (Figure 1, section I). If necessary, the matrix enables the observation of the variation of ecosystem services over the course of time as it is likely that in time the status of the water body will change and so will its service capacity. It is also possible to determine and assess the actual ecosystem service supply of a specific river with the help of the matrix for determination and valuation of river ecosystem services in Appendix 1.

The ecosystem services index (ESSI) allows for the comparison of ecosystem service capacities of water bodies. ESSI has been developed after the MESLI index (multiple ecosystem services landscape index; Rodrígues-Loinaz et al., 2015). The following formula is used to calculate ESSI:

$$\mathrm{ESSI} = \frac{\sum_i^n (x - xmin)}{\sum_i^n (xmax - xmin)} \quad (1)$$

where

n= number of ecosystem services

x= assessment of (i) ecosystem service

x_{min} = 0 (the lowest ecosystem service value on the assessment scale used in the project)

x_{max} = 4 (the highest ecosystem service value on the assessment scale used in the project)

The larger and more natural the water body, the higher the ESSI value. A higher ESSI value indicates that a water body has a more significant supply of services than estimated, and that a larger amount of services will actually be consumed.

2. Methods for determining lake' ecosystem services

Spatially, the methodology for determining the ecosystem services of lakes relates to the open water, littoral zone and shore. The latter is 15 metres inland from the edge of the shoreline, i.e. from the maximum range of flooded area. The main idea behind the methodology is that the amount and value of the ecosystem services of a lake depend on its characteristics determined by morphological features as well as ecological and chemical status within the meaning of the 28.07.2009 Regulation No. 44 (RTL, 2009, 941) of the Minister of the Environment. The assessment scales for ecological and chemical statuses can be found in columns 2 and 3 of Table 1. Among the hydro-morphological features that characterise the status of a lake, such as the water regime and morphometry (size, depth, coastline structure, water exchange, etc.) are used. The surface area (*area, ha*) and maximum depth ($depth_{max}$, m) of the lake for describing of ecosystem services have taken into consideration according to the following formula:

$$MOI = \ln(\frac{area}{depth_{max}}) \quad (2)$$

The morphometry index, or MOI, has been calculated for 503 small lakes in Estonia. Lakes are divided into three classes according to their index value: large (>3), average (0,8-3), small (<0,8). (See also column 2 of Table 1.)

A list of direct ecosystem services of lakes can be found in Table 3.

Table 3. Lake ecosystem services (P - provisioning, R - regulating and maintaining, C - cultural and Ab - abiotic services)

Service group	Service	Explanation
P	Fish stock (commercial fishing)	3 large and 11 small lakes were used for professional fishing in 2015. Leisure fishing is part of cultural services.
P	Reed (material)	Mainly common reed.
P	Surface water supply (drinking water)	The actual situation and possibilities are assessed. The assessment does not take into account that by implementing thorough purification methods any water can be made drinkable.
P	Surface water supply (for purposes other than drinking)	E.g. irrigation water, blow out water, cooling water, industrial water, etc. Takes into account the actual situation and possibility of water use.
R	Habitat maintenance	E.g. larger, deeper lakes with a more complex coastline provide more diverse habitats.
R	Protected species and key species, natural habitats and maintenance of the balance between them	This is a very valuable and important service —a quantitative balance between the communities exists when there is high abundance of species, and species both rare and characteristic to the lake are present.

R	Maintenance of natural state of water (natural water quality, wastewater dilution, self-purification)	The strength of the ecosystem in ensuring natural processes is assessed, and how the waterbody is able to keep these processes under control.
R	Maintenance of hydrodynamics and flood protection	Not a very important service for lakes. In principle, for example, in spring Lake Võrtsjärv draws water from the rivers downstream, and thus acts as a buffer.
C	Environmental conditions suitable for recreation (by type)	E.g. walking on the shore, sunbathing, bathing, swimming, enjoying views, boating on the lake etc.
C	Environmental conditions suitable for leisure fishing and hunting (by type)	Assessment of fish and game stock and the infrastructure required for fishing and hunting.
C	Catching of crayfish	
C	Opportunity for research	The special features and properties leading to the research potential of the lake are assessed.
C	Opportunity for education	Conditions suitable for outdoor study.
C	Source of inspiration for creative activity	Assessing the service is very subjective since creative activity is stimulated by very different aspects.
C	Natural symbols (spiritual sites, national symbols)	Sacred places acknowledged by society, national symbols.
Ab	Hydrothermal energy	
Ab	Transport (shipping and ice roads)	Navigation (navigable lakes) or winter transport (official ice road). Does not include boating for recreational purposes, fishing, and rides with motor vehicles or off-road vehicles.
Ab	Mud supply (for therapy and agricultural purposes)	Mud therapy, complementary feedingstuffs for animals, fertilisers for organic farming, etc.

Depending on the morphological, ecological and chemical status of the lake, the matrix in Appendix 2 can be used for assessing the potential of ecosystem services of lakes. The assessments included in the fields of the matrix about the potential of ecosystem services come from lake experts and have been verified on the basis of pilot areas both by means of focus group interviews and specific numeric values of existing indicators. The assessments can be mapped and provide an initial overview of ecosystem services of lakes (Figure 1, section I). If necessary, the matrix makes it possible to observe the ecosystem services change during the course of time as in time the status of a waterbody and its capacity for services can change. It is also possible to determine and assess the actual ecosystem service supply of a specific lake with the help of the matrix for determination and valuation of ecosystem services of lakes in Appendix 2.

3. Methods for determining ecosystem services of the coastal sea

The matrix for determination and valuation of coastal sea ecosystem services (Appendix 3) has been created by experts of the field with the consideration that the availability of ecosystem services depends on the ecological status of the coastal sea [within the meaning of the 28.07.2009 Regulation No. 44 (RTL 2009, 64, 941) of the Minister of the Environment] and the associated shoreline geology (Tõnisson *et al*, 2013). The assessment scale for ecological status can be found in column 3 of Table 1

and the expert assessment scale for ecosystem services can be found in column 5. The classification of shoreline geology characterising shoreline sensitivity to pollution, can be found in Table 4.

Table 4. The geological properties of shore and its sensitivity to pollution

Silty shore: depositional with fine-grained (silt) sediments, often covered by reed-beds, meadows on grazed areas, usually it has a flat nearshore and a tendency to become overgrown		
Till shore: less-exposed (to wave activity) shores are often covered by reed-beds, shores well-exposed to wave activity are often covered by abrasion paving (similar to rip-rap)		
Gravel-pebble shore: sometimes mixed with sand, in regions with very intense wave activity		
Sand shore: often dunes, recreationally valuable beaches		
Artificial shore: artificial constructions (harbours, concrete walls, etc.)		
Cliffed shore: cliff with occasional signs of erosion in resistant Palaeozoic rocks (limestone, dolomite, sandstone)		
Very sensitive to pollution	Medium or large sensitivity to pollution	Low sensitivity to pollution

A list of direct ecosystem services of coastal seas area can be found in Table 5.

Table 5. Coastal sea ecosystem services (P - provisioning, R - regulating and maintaining, C - cultural and Ab - abiotic services)

Service group	Service	Explanation
P	Algae stock	For food, feedingstuffs, fertilisers, etc.
P	Herbal biomass of coastal grasslands	Coastal grasslands for grazing and harvesting feedingstuffs.
P	Fish stock (commercial fishing)	Leisure fishing is part of cultural services.
P	Reed (material)	Mainly for building materials and fuel.
R	Habitat maintenance	The shallow sea, large areas overgrown with reed and complex coastline configuration provide very different habitats.
R	Maintenance of natural water (natural water quality, wastewater dilution, self-purification).	The capacity for self-purification is increased by filter feeders such as *Dreissena polymorpha.*
R	Protected species and key species, natural habitats and maintenance of the balance between them	This is a very valuable and important service — a quantitative balance between the communities exists when there is an abundance of species, and species both rare and characteristic to the waterbody are present.
R	Natural sedimentation and transport of sediments, erosion regulation	The less man-made structures alter the course of ecological processes of the coast, the more natural the sedimentation. The sea area is affected by large-scale use of small boats and watercraft, also by cutting of sediments.
R	Maintenance of hydrodynamics and flood risk mitigation	
C	Environmental conditions suitable for recreation (by type)	E.g. walking on the shore, sunbathing, bathing, swimming, enjoying views, use of watercraft for recreational purposes, etc.

C	Environmental conditions suitable for leisure fishing and hunting (by type)	Assessment of fish and game stock and the infrastructure required for fishing and hunting.
C	Source of inspiration for creative activity	Assessing the service is very subjective since creative activity is stimulated by very different aspects.
C	Opportunity for research	Assessment of the characteristics of the coastal sea and its potential for research.
C	Opportunity for education	Conditions suitable for outdoor study.
C	Natural symbols (spiritual sites, national symbols)	Sacred places acknowledged by society, national symbols, e.g. large stones and cliffs.
Ab	Environmental conditions suitable for the production of wind energy	Construction of wind parks and recreation areas are mutually exclusive activities.
Ab	Environmental conditions suitable for the production of hydrothermal energy	
Ab	Environmental conditions suitable for navigation (incl. cooling water, bilge water etc.)	
Ab	Environmental conditions suitable for the construction of ice roads	Navigation (navigable rivers) or winter transport (official ice road). Does not include boating for recreational purposes, fishing, and rides with motor vehicles or off-road vehicles.
Ab	Mud supply (for therapy and agricultural purposes)	Mud therapy, complementary feedingstuffs for animals, fertilisers for organic farming, etc.

The marine environment in the matrix (Appendix 3) has been divided into three categories/biomes: the coastal sea, open sea (pelagic) and open sea (benthic). The coastal sea lies from shoreline to 20 metre isobaths. Whether the services are those of the pelagic (water column) or benthic (seabed) parts of the sea, is not differentiated, as these parts are very closely interconnected in shallow marine areas. The open sea environment makes it possible to determine services separately for the pelagic or benthic zones.

The matrix for marine ecosystem services cannot provide a clear assessment of the following services: maintenance of natural sedimentation and free motion of sediments, erosion regulation and flood risk mitigation. Maintenance of natural sedimentation, free motion of sediments and erosion regulation are independent of the status of the ecosystem. Seabed geology is important here. If the deterioration of the status of the ecosystem causes changes in currents and water flow, it also brings about changes in services. Rocky shores and cliffs are erosion-secure, soft surfaces are more sensitive to it. Flood risk mitigation also depends on seabed geology - large sandy sea floor without flora increases flood risk.

The assessments can be mapped and provide an initial overview of coastal sea ecosystem services (Figure 1, section I). If necessary, the matrix makes it possible to observe the ecosystem services change during the course of time as in time the status of a waterbody and its capacity for services can change. It is also possible to determine and assess the actual ecosystem services of a specific coastal water body based on the matrix for determination and valuation of ecosystem services of coastal waters provided in Appendix 3.

Marine ecosystem services are determined quantitatively on the basis of the DPSI(W)R and the good environmental status of the marine area, as well as on the basis of related indicators within the meaning of the EU Marine Strategy Framework Directive (Figure 1, section II). The methodology includes four stages:

1) By using relevant maps, a marine area of interest is chosen, and important services supplied by the marine ecosystem are determined (the matrix in Appendix 3 can be used for this);
2) By using suitable pressure indicators provided in the Marine Strategy Framework Directive (MSFD) and relevant maps, important environmental pressure factors — and the extent of these factors — related to the use of important marine ecosystem services are determined and characterised;
3) The status of the ecosystem services is assessed based on relevant maps and biological data, results of the geostatistical analysis and relevant values of MSFD status indicators;
4) The following effects resulting from the use of important services are assessed: 1) the extent of the public good (e.g. financial gain from fishing) and 2) pressure on the ecosystem; also, the relevant pressure-state characteristics are described by using suitable biological and socio-economic as well as MSFD pressure indicators;
5) By using the relevant counter effect/response indicators, the relevance, adequacy and efficiency of enforcement of countermeasures (preventive and mitigating measures) implemented during the use of services, is assessed.

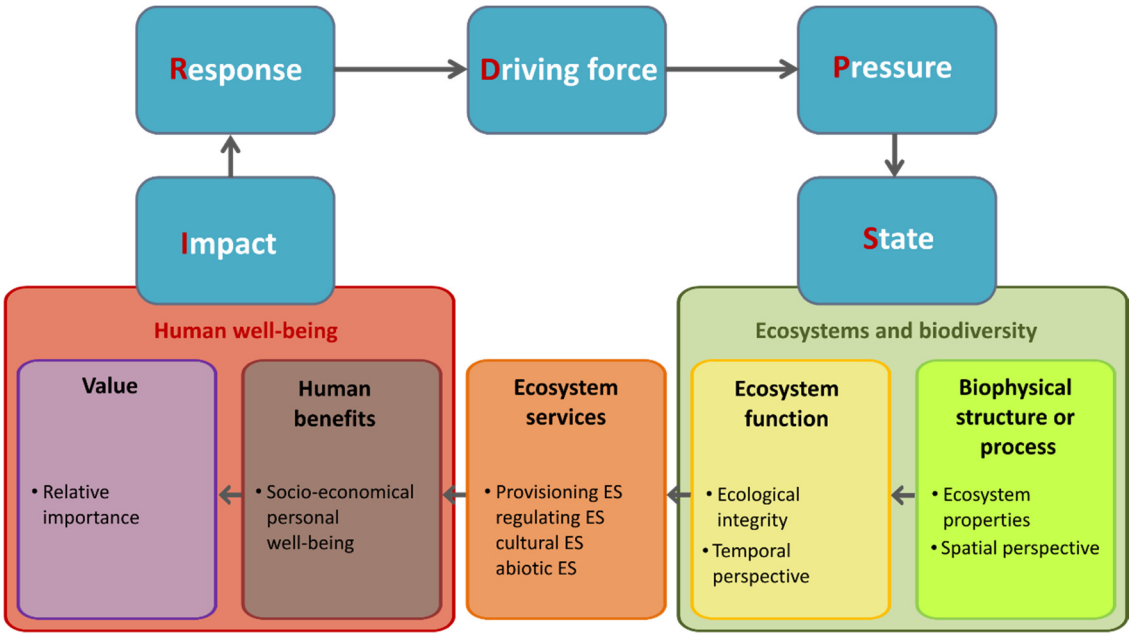
The quantitative determination and assessment of the sustainable use of marine ecosystem services that are based on the DPSI(W)R model rely on concrete measurable indicators, is of universal nature and can be used for any marine area.

4. Ecosystem service indicators for rivers, lakes, and coastal seas

The status of an ecosystem cannot be assessed on the basis of individual factors, a coherent system of indicators must be used instead. For this purpose, Estonia has adopted the DPSIR environmental indicators system; developed by the European Environment Agency, the system is made up of five interconnected units of indicators:

- D – driving force;
- P – pressure;
- S – state;
- I – impact;
- R – response.

Pressure (P) proceeds from driving force (D) and brings about a change in state (S). This will manifest itself as changes in the ecosystem and will affect the processes, general integrity and functions of the ecosystem that supply people with services. When an ecosystem loses its value to people, human well-being measured by indicators of impact (I) will suffer from it. The identification of changes in the status of an ecosystem and effects of the changes provides a basis for the implementation of measures (R). The purpose for the use of measures is to mitigate the pressure (P) resulting from the initial driving force. Such a cycle for managing the use of environment ensures a sustainable use and protection of the ecosystem and its services.



Joonis 2. The connection between DPSIR environmental indicators system and ecosystem services (Mononen *et al*, 2015).

For the assessment of services of rivers, lakes and the coastal sea, a goal was set on the basis of the CICES classification of ecosystem services, the DPSIR model of environmental indicators and the experience of other countries in the development of systems of ecological indicators, to identify scientific, measurable, representative, sensitive, clear and available indicators that could be mapped and would describe the relationship between processes.

Tables 1-3 in Appendix 4 contain excerpts of ecosystem service indicators of rivers, lakes and the coastal sea. For every service there is a system of indicators that should cover the entire DPSIR framework or at least the PSR framework. In some cases, more than one DPSIR type indicator was developed. For example, there are 6 indicators (Appendix 4, Table 1) to help classify the status of habitats maintenance services of lakes, which makes it possible to choose the most suitable indicator. Coastal sea has the most indicators, because it also includes the largest number of specific services that are not used in the context of Estonian rivers and lakes, or are used very little (e.g. the use of algae as raw material, industrial fishing, environmental conditions suitable for the production of wind energy, etc.). Of course, the freshwater ecosystems have their specific services as well (such as surface water for drinking, hydro-energy), but marine areas have the largest diversity of services (Table 6).

Table 6. The allocation of indicators by ESS sections developed during the project

Number of indicators	Lake (n=131)	River (n=124)	Sea (n=156)
Provisioning services	23	15	25
Regulating and maintenance services	45	51	61
Cultural services	48	47	39
Abiotic services	15	11	31
TOTAL	131	124	156

5. Overview of methods for mapping ecosystem services

Marine and inland waters ecosystems provide various services, the determination, assessment and mapping of which is necessary for assessing key factors (e.g. land/sea-use), different effects (e.g. air pollution, climate change) in time and space and understanding the relationship between them. Mapping of services requires professional skills and flexibility since the assessment of ecosystem services is dependent on the existence of primary data and the consistency and interconnectability of the data.

The maps reflecting the use of land cover and land make up the base material for mapping ecosystem services. The base data can be obtained from topographic maps, remote-sensing data and different studies. The most readily available data for this is the CORINE Land Cover database that covers most European countries. The advantage of CORINE is that it provides a comparison between countries. However, the problem with CORINE is that it provides very general information and thus is not suitable for use at local levels. For a more comprehensive assessment of ecosystem services the topographic data needs to be linked to other qualitative and quantitative data (i.e. human activity, hydrology, soils, climate, etc.), combining it with land cover data and remotely sensed land-use data. There may be many suitable indicators for the assessment of ecosystem services, but base spatial data necessary for mapping may still be lacking, which is why finding suitable indicators for mapping may turn out to be more difficult that initially thought (Kalvane *et al*, 2014).

In the case of ecosystem services, both supply and demand can be mapped. The mapping mostly relies on expert assessments, biophysical factors (i.e. numeric figures of indicators), economic value, or social research.

Expert assessments are considered to be the fastest way of getting necessary information. This method relies on specific expert knowledge and experience of a specific area. The mapping is based on a matrix that is developed by experts who on a pre-agreed scale (e.g. 0-4) assess the capacity of an area to provide services. The results provide a basis for the creation of maps (see Figure 3.1).

The positive aspect of the matrix is that it is simple and logical; on the other hand, it carries a risk of oversimplification. In order to decrease this risk, the verification of the reliability of the model, suitability of experts and scientific quality has been proposed. The maps created on the basis of expert assessments are more suitable for use at national and local levels because the heterogeneity of different types of land cover might not be distinguishable on a wider scale (Stoll *et al*, 2015).

The mapping of the biophysical values of the ecosystem is based on determination, measurement and assessment of the ecosystem with the aim of understanding how the ecosystem works and what kind of services it provides. The important first stage of this method is finding the suitable indicators and primary data describing these indicators. This results in a map reflecting the service potential of the ecosystem (see Figure 3.2). The actual supply of services is reflected via a specific input - an additional effect upon which the actual realisation (e.g. nutrient load, tourism flow, flood frequency, etc.) of the potential based on biophysical parameters depends on. This makes it possible to show different scenarios and assess changes in the service supply of ecosystems.

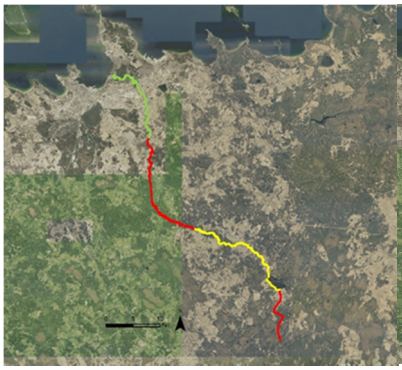


Figure 3.1. Fish stock of the Pirita River based on expert estimates.

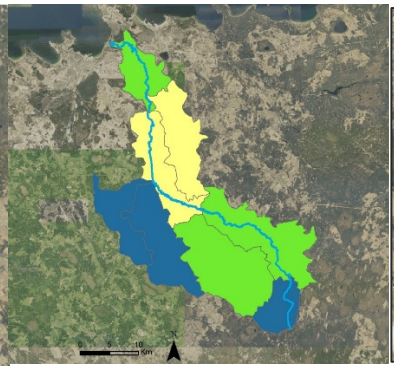


Figure 3.2. The habitats and the habitats maintenance service of the Pirita River by protected areas based on indicators.

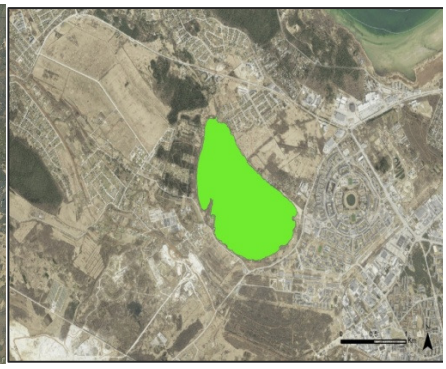


Figure 3.3. People's willingness to pay for the improvement of the environmental conditions of Lake Harku from a status of bad to a status of poor (notional assessment method).

When assessing economic value, the qualitative and quantitative data of the ecosystem services can be converted into financial units and the geographic variation of the results can be mapped (see Figure 3.3). Depending on the purpose of research, experience, the chosen method for the assessment of economic value, the possibilities for assessing economic value and mapping the results are quite diverse.

When assessing socio-cultural values, the focus is on (local) people's vision of and their need for ecosystem services, or, in other words, the demand for ecosystem services. The primary task in implementing this measure is to correctly determine the stakeholders with who surveys, interviews, mapping and other similar exchanges of views are to be conducted. Various public engagement GIS platforms can be used for mapping, such as *Maptionnaire* or models such as *SolVES* that can be integrated with the ArcGIS software. Choosing the suitable platform or model depends on the purpose of the research and to a large extent on financial resources, because generally the license of the platforms can be quite expensive.

When mapping ecosystem services, it is advisable to take into account that the methods described here are complementary and vary in scientific accuracy (see Figure 4). Choosing a suitable mapping methodology depends on several circumstances: the ecosystem service to be assessed, availability of primary data, time, and financial resources, as well as the client's wishes. However, the methods described here are not the only methods possible. They can be adjusted according to the situation and the ecosystem service observed.

Although within the framework of the project the mapping of ecosystem services was tested on pilot areas, the mapping should be conducted as a spatial whole (e.g. on catchment basis) to obtain a more comprehensive view. It is important to include experts of the field in the mapping process. This way it is possible to use expert knowledge in the assessment and mapping (incl. the adjustment of methods) of ecosystem services, and it will help prevent mapping errors.

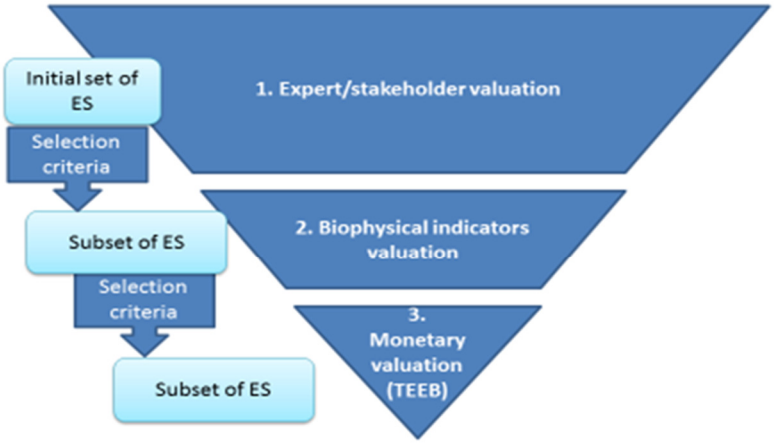


Figure 4. Mapping methodologies and their their interrelationship.

6. Recommendations for the calculation of the monetary value of ecosystems

In this report, the assessment of the monetary value of marine and inland ecosystem services are treated as part of political and/or resource management choices. The economic value of ecosystem services can provide the information on whether the planned policy change affecting the functioning of the ecosystem provides the society or community with net income and well-being; support the selection of the most affordable alternative and prioritisation of objects/activities that are to be funded; identify situations where there is a choice between the use of competing ecosystem services (e.g. land and sea use); and provide an assessment of environmental damage; and create a basis for discussion with the public and developers regarding the value and importance of the environment and the ecosystem services.

The assessment of the economic value of ecosystem services uses the so-called impact pathway approach. In this approach, the impact of the change is examined, starting with the source of change and ending with the positive or negative impact (damage) on public health, property and/or the natural environment (see Figure 5). Thus, the assessment of economic value also needs to take into account the relationship/linkages between the impact on the ecosystem and the following impacts on the society's welfare.

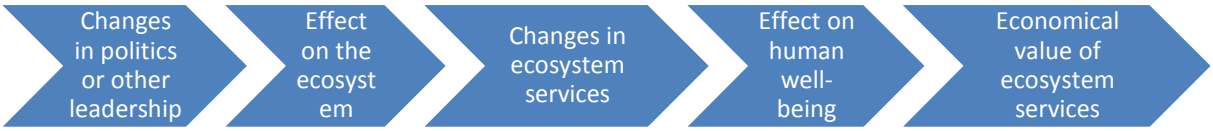


Figure 5. A simplified example of the impact pathway of political changes.

The methods used for determining the economic value of ecosystem services are grouped together in Table 7. The table shows which method could be used for determining the economic value of a specific service.

Table 7. Methods for calculation of monetary value of marine and inland water ecosystem services

Ecosystem services		Market or non-market goods	Use and non-use value	Monetary valuation methods
P	Fish stock (commercial fishing)	Market and non-market goods	Direct and indirect use	Market valuation, factor income, contingent valuation, choice experiments, benefit transfer
P	Materials (reed)	Market and non-market goods	Direct and indirect use	Market valuation, factor income, contingent valuation, choice experiments, benefit transfer
P	Surface water supply (drinking water)	Market and non-market goods	Direct and indirect use	Market valuation, factor income, contingent valuation, choice experiments, benefit transfer
P	Surface water supply (for purposes other than drinking)	Market and non-market goods	Direct and indirect use	Market valuation, factor income, contingent valuation, choice experiments, benefit transfer
R	Habitat maintenance	Market and non-market goods	Direct and indirect use	Market valuation, contingent valuation, costs-based, choice experiments, benefit transfer
R	Protected species and key species, natural habitats and maintenance of the balance between them	Market and non-market goods	Direct and indirect use	Market valuation, costs-based, contingent valuation, choice experiments, benefit transfer
R	Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Market and non-market goods	Direct use	Market valuation, factor income, costs-based, contingent valuation, choice experiments, benefit transfer
R	Maintenance of hydrodynamics and flood protection	Market and non-market goods	Direct use	Market valuation, factor income, costs-based, contingent valuation, choice experiments, benefit transfer
C	Environmental conditions suitable for recreation (by type)	Market and non-market goods	Direct use	Market valuation, factor income, travel costs, costs-based, contingent valuation, choice experiments, benefit transfer

C	Opportunity for research; opportunity for education	Market goods	Direct use	Market valuation, benefit transfer
Ab	Mud supply (for therapy and agricultural purposes)	Market and non-market goods	Direct and indirect use	Market valuation, factor income, benefit transfer

Important stages in the process of assessing economic value are as follows:

1. Determination of the baseline situation for the current environmental state.
2. Determination and qualitative assessment (focusing on the most important) of the potential impacts of policy options i.e. alternative scenarios on on ecosystem services.
3. Quantification of impacts of policy options on chosen ecosystem services (for example, using indicators to determine levels).
4. Assessment of changes that affect human well-being (what, if any, benefits are increased or decreased).
5. Value the changes in ecosystem services. (Also see Figure 1.)

There is a wide range of methods for assessing the value of ecosystem services. The ecosystem services that are tradable and/or have a direct use value can be valued on the basis of the following: market valuation, factor income, costs based (avoided, replacement and restoration costs), hedonic pricing and travel cost methods. The advantage of these methods is that they are rather straight forward to use and provide faster results, since information about market price is usually readily available. However, depending on the method, the amount of data may be large and working with it might be time-consuming. The main disadvantage of the method is the fact that it enables valuation of only tradable services (for example, some provisioning services).

For the assessment of ecosystem services that produce public goods, indirect assessment methods like stated preference methods (contingent valuation and discrete choice experiments) would be used. Both methods are based on a hypothetical market situation in which the respondents are asked about their preferences and willingness to pay. A questionnaire for the introduction of a hypothetical market is prepared and the survey is conducted via the Internet, by phone or through face-to-face interviews. In addition to public goods, these methods can be used for valuation of tradable goods and services. The implementation of these two methods is a substantial and rather time consuming task.

The contingent valuation method allows for the assessment of only the total value of ecosystem services (but not a marginal value); the marginal value of ecosystem services can be assessed when using the discrete choice experiment method. Compared to discrete choice experiment, the contingent valuation usually has a lower cost and a shorter time scale, the questionnaire is less complex to prepare, is easier for the respondents to comprehend and does not require specific software for analysing. The questionnaire also carries a higher risk of biased answers, and the respondents' preference consistency is lower.

In the case of discrete choice experiment, the preparation of the questionnaire and tests, as well as the process of replying, is more complex, data analysis requires specific software, and thus the cost is

usually higher. Thanks to the design generated by the software, the discrete choice method has a lower risk of biased answers, and respondent preferences are more consistent.

In addition to direct and indirect assessment methods, there is the value-transfer method in which the results of past surveys are adjusted for new cases or locations. The creation of similar premises and situations is of critical importance for this method. The usability of value-transfer methods can be increased through applicability tests and comparing the results with original studies. A list of methodologies with the explanation of the advantages and disadvantages of each method for determining the monetary value of ecosystem services can be found in Appendix 5.

During the course of this study the indirect methods of contingent valuation and discrete choice experiment methods were tested. Both methods were simultaneously used for the case study of Lake Harku, while only the contingent valuation method was used for the Linnamäe barrage (Jägala River). It is possible to conclude on the basis of the conducted studies that residents highly value the benefits provided by nature and are willing to contribute financially to the maintenance and improvement of these benefits. In addition it can be said, based on the case studies conducted, that the objective set at the start of the value assessment process, the ecosystem services determined, and the clear description of policy choices - what is assessed in terms of impact and change, and why - are of key importance.

Assessment of economic value is very closely connected to the understanding of the functioning of the ecosystem and the ability to proficiently convey that knowledge to the respondents. Professional and objective baseline data on "cause and effect" as well as possible impacts on residents and change in their welfare is of critical importance. Balanced preparation of questionnaires and the inclusion of affected parties in prior testing of the questionnaire is essential. The survey can be tested through one-on-one interviews, focus group debates or panel discussions.

Based on experience and a literature review, it should be stressed that the assessment of the economic value of ecosystem services needs to consider a body of water, not just as a river or a lake, but as a catchment area. The catchment area is the level at which human impact affect the ecosystem of a water body and where the changes in the benefits provided by the ecosystem affect the welfare of residents who reside directly in the catchment area and who are then impacted by policies and development projects. However, the choice of object and methodology for the assessment of economic value depends primarily on necessity.

References

Common International Classification of Ecosystem Services (CICES). 2013. [Online] http://cices.eu/

Kalvane I., Burkhard B., Ruskule A., Bojars E. 2014. Methodological Guidelines for Mapping and Assessment of Grassland Ecosystem Services. Baltic Environmental Forum – Latvia, pp. 30.

Loigu E., Pachel K., Kaju O., Elken R., Raudsepp K., Kuusik A., Sokk O. 2014 project report "Assessment of the hydro-morphological state of (artificial or heavily modified) flowing water bodies that have been seriously affected either by natural conditions or human activities and elaboration of the methodology for assessment of their state". Tallinn University of Technology, Faculty of Civil Engineering, Department of Environmental Engineering http://www.envir.ee/sites/default/files/vooluveekogude_hindamise_metoodika_aruanne.pdf

Millennium Ecosystem Assessment (MEA). 2005. *Ecosystems and Human Well-being: Synthesis*. Island Press, Washington

Mononen L., Auvinen A.-P., Ahokumpu A.-L., Rönkä M., Aarras N., Tolvanen H., Kamppinen M., Viirret E., Kumpula T., Vihervaara P. 2015. National ecosystem service indicators: Measures of social–ecological sustainability. Ecological Indicators, doi:10.1016/j.ecolind.2015.03.041

Formation of surface waters, and a list of surface waters the status class of which needs to be determined; status classes of surface waters and quality indicators corresponding to status classes, and designation of status classes. (RTL 2009, 64, 941) [Online] https://www.riigiteataja.ee/akt/13210253?leiaKehtiv

Rodríguez-Loinaz G., Alday J.G. & Onaindia M. 2014. Multiple ecosystem services landscape index: A tool for multifunctional landscapes conservation. J. Environ. Manage. 147: 152– 163.

Stoll, S., Frenzel, M., Burkhard, B., Adamescu, M., Augustaitis, A., Baeßler, C., Bonet Garcia, F.J., Cazacu, C., Cosor, G.L., Diaz-Delgado, R., Carranza, M.L., Grandin, U., Haase, P., Hämäläinen, H., Loke, R., Müller, J., Stansisci, A., Staszewski, T., Müller, F. 2015. Assessment of ecosystem integrity and service gradients across Europe using the LTER Europe Network. Ecological Modelling. Volume 295. pp. 75-87

The Economics of Ecosystems and Biodiversity (TEEB). 2008. The economics of ecosystems and biodiversity: An interin Report. [Online] http://www.teebweb.org/media/2008/05/TEEB-Interim-Report_English.pdf

Tõnisson H., Orviku K., Jaagus J., Suursaar Ü., Kont A., Rivis R.. 2008. Coastal Damages on Saaremaa Island, Estonia, Caused by the Extreme Storm and Flooding on January 9, 2005. Journal of Coastal Research, 24 (3), 602 - 614

Appendices

Appendix 1. Matrix for determination and assessment rivers' ecosystem services

Characteristics				Provisioning services				Regulating and maintaining services				Cultural services						Abiotic services		Remarks
Hydromorphological status	Ecological status	Ecological status, fish	Chemical status	Fish stock (commercial fishing)	Surface water supply (drinking water)	Water for shellfish and fish farming (in aquaculture)	Water for industrial and agricultural use	Habitat maintenance	Preservation of protected and key species	Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Maintenance of hydrodynamics and flood protection	Environmental conditions suitable for recreation (by type)	Environmental conditions suitable for leisure fishing and hunting (by type)	Opportunity for research	Opportunity for education	Source of inspiration for creative activity	Natural symbols (spiritual sites, national symbols)	Hydropower	Transport (shipping and ice roads)	
				P	P	P	P	R	R	R	R	C	C	C	C	C	C	Ab	Ab	
very strong human impact	bad		bad	0	0	0	2	0	0	1	1	0	0	1	1	1	0	3	3	
			good	0	1	1	3	1	1	1	1	1	0	1	1	1	0	3	3	
	poor		bad	0	0	0	2	0	0	1	1	0	0	1	1	1	0	3	3	
			good	0	1	1	3	1	1	1	1	1	0	1	1	1	0	3	3	
	moderate		bad	0	0	0	2	0	0	1	1	1	0	1	1	1	0	3	3	
		good or high	good	2	2	2	3	1	1	2	1	2	2	1	2	2	0	3	3	
		moderate		1	2	2	3	1	1	2	1	1	1	1	2	2	0	3	3	
	good		bad	0	0	0	2	0	0	1	1	1	0	1	1	1	0	3	3	Unlikely combination
			good	2	3	3	3	2	2	3	1	2	2	1	3	3	0	3	3	
	high		bad	0	0	0	2	0	0	3	1	2	0	1	2	2	0	3	3	Unlikely combination
			good	3	4	4	4	2	2	3	1	2	2	1	3	3	0	3	3	Unlikely combination
strong human impact	bad		bad	0	0	0	2	0	0	0	1	0	0	1	1	1	1	3	3	
			good	0	1	1	2	1	1	1	1	1	0	1	1	1	1	3	3	
	poor		bad	0	0	0	2	0	0	1	1	1	0	1	1	1	1	3	3	Unlikely combination
			good	0	1	1	2	1	1	2	1	1	0	1	1	1	1	3	3	
	moderate		bad	0	0	0	2	0	0	1	1	1	0	1	1	1	1	3	3	Unlikely combination
		good or high	good	3	2	2	3	3	3	2	2	2	3	1	3	3	1	3	3	
		moderate		0	2	2	3	2	2	2	1	1	1	1	2	2	1	3	3	
	good		bad	0	0	0	2	0	0	1	1	1	0	1	3	3	1	3	3	Unlikely combination
			good	3	3	3	4	3	3	2	1	2	3	1	3	3	1	3	3	
	high		bad	0	0	0	2	0	0	1	1	2	0	1	2	2	1	3	3	Unlikely combination
			good	3	4	4	4	3	3	3	1	2	3	1	3	3	1	3	3	Unlikely combination
moderate human impact	bad		bad	0	0	0	2	0	0	1	2	0	0	1	1	1	2	2	2	Unlikely combination
			good	0	0	0	3	1	1	2	2	1	0	1	1	1	2	2	2	
	poor		bad	0	0	0	2	1	1	1	2	1	0	1	1	1	2	2	2	
			good	0	2	1	3	2	2	2	2	2	1	1	1	1	2	2	2	
	moderate		bad	0	0	0	2	0	0	1	2	1	0	2	2	2	2	2	2	Unlikely combination
		good or high	good	3	2	2	3	3	3	2	2	3	3	3	3	3	2	2	2	
		moderate		1	2	2	3	2	2	2	2	2	1	2	2	2	2	2	2	
	good		bad	0	0	0	2	0	0	1	2	2	0	2	2	2	2	2	2	Unlikely combination
			good	2	3	3	3	3	3	3	2	3	3	2	3	3	2	2	2	
	high		bad	0	0	0	2	0	0	1	2	2	0	2	2	2	2	2	2	Unlikely combination
			good	3	4	4	4	3	3	3	2	3	3	3	3	3	2	2	2	

Characteristics				Provisioning services				Regulating and maintaining services				Cultural services						Abiotic services		Remarks
Hydromorphological status	Ecological status	Ecological status, fish	Chemical status	Fish stock (commercial fishing)	Surface water supply (drinking water)	Water for shellfish and fish farming (in aquaculture)	Water for industrial and agricultural use	Habitat maintenance	Preservation of protected and key species	Maintenance or natural water (natural water quality, wastewater dilution, self-purification)	Maintenance of hydrodynamics and flood protection	Environmental conditions suitable for recreation (by type)	Environmental conditions suitable for leisure fishing and hunting (by type)	Opportunity for research	Opportunity for education	Source of inspiration for creative activity	Natural symbols (spiritual sites, national symbols)	Hydropower	Transport (shipping and ice roads)	
				P	P	P	P	R	R	R	R	C	C	C	C	C	C	Ab	Ab	
small human impact	bad		bad	0	0	0	2	0	0	0	3	0	0	1	2	2	3	1	1	Unlikely combination
			good	0	0	0	3	1	1	1	3	1	1	1	2	2	3	1	1	Unlikely combination
	poor		bad	0	0	0	2	0	0	0	3	1	0	1	2	2	3	1	1	Unlikely combination
			good	0	0	1	3	1	1	1	3	1	1	2	2	2	3	1	1	Unlikely combination
	moderate		bad	0	0	0	2	0	0	1	3	1	0	2	2	2	3	1	1	Unlikely combination
		good or high	good	3	2	2	3	3	3	2	3	3	3	3	3	3	3	1	1	
		moderate		1	2	2	3	2	2	2	3	2	2	3	3	3	3	1	1	
	good		bad	0	0	0	2	0	0	1	3	2	0	2	3	3	3	1	1	Unlikely combination
			good	4	4	4	4	4	4	4	3	3	4	3	4	4	3	1	1	
	high		bad	0	0	0	2	0	0	1	3	2	0	3	3	3	3	1	1	Unlikely combination
			good	4	4	4	4	4	4	4	3	4	4	4	4	4	3	1	1	
natural	bad		bad	0	0	0	2	0	0	0	4	0	0	1	2	2	4	0	0	Unlikely combination
			good	0	0	1	3	1	1	1	4	1	1	1	3	3	4	0	0	Unlikely combination
	poor		bad	0	0	0	2	0	0	0	4	1	0	1	2	2	4	0	0	Unlikely combination
			good	0	0	2	3	1	1	1	4	2	1	1	3	3	4	0	0	Unlikely combination
	moderate		bad	0	0	0	2	0	0	1	4	2	0	3	2	2	4	0	0	Unlikely combination
		good or high	good	3	3	3	3	3	3	2	4	4	3	3	3	3	4	0	0	
		moderate		2	3	3	3	2	2	2	4	3	2	3	3	3	4	0	0	
	good		bad	0	0	0	2	0	0	1	4	2	0	2	3	3	4	0	0	Unlikely combination
			good	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	
	high		bad	0	0	0	2	0	0	2	4	2	0	2	3	3	4	0	0	Unlikely combination
			good	4	4	4	4	4	4	4	4	4	4	4	4	4	4	0	0	

Appendix 2. Matrix for determination and assessment lakes' ecosystem services

Characteristics			Provisioning services				Regulating and maintaining services				Cultural services							Abiotic services		
Morphological index	Ecological status	Chemical status	Fish stock (commercial fishing)	Reed (material)	Surface water supply (drinking water)	Surface water supply (for purposes other than drinking)	Habitat maintenance	Protected species and key species, natural habitats and maintenance of	Maintenance of natural state of water (natural water quality, wastewater dilution, self-purification)	Maintenance of hydrodynamics and flood protection	Environmental conditions suitable for recreation (by type)	Environmental conditions suitable for leisure fishing and hunting (by type)	Catching of crayfish	Opportunity for research	Opportunity for education	Source of inspiration for creative activity	Natural symbols (spiritual sites, national symbols)	Hydrothermal energy	Transport (shipping and ice roads)	Mud supply (for therapy and agricultural purposes)
			P	P	P	P	R	R	R	R	C	C	C	C	C	C	C	Ab	Ab	Ab
small	bad	bad	0	1	0	1	0	0	0	0	0	0	0	4	4	1	1	3	2	0
		good	0	1	0	1	0	0	0	0	1	1	0	4	4	2	1	3	2	1
	poor	bad	0	1	0	1	0	0	0	0	0	0	0	4	4	2	1	3	2	0
		good	0	1	0	1	0	0	0	0	1	1	1	4	4	2	1	3	2	1
	moderate	bad	0	1	0	1	0	0	0	0	1	1	0	4	4	2	1	3	2	0
		good	0	1	0	1	1	1	0	0	1	2	2	4	4	2	1	3	2	1
	good	bad	0	1	0	1	1	1	1	0	1	2	0	4	4	2	1	3	2	0
		good	0	1	0	1	2	2	1	0	2	2	2	4	4	2	1	3	2	1
	high	bad	0	1	0	1	1	1	0	0	2	2	0	4	4	2	1	3	2	0
		good	0	1	0	1	2	2	1	0	2	2	2	4	4	2	1	3	2	1
average	bad	bad	2	1	0	1	0	0	0	1	1	0	0	4	4	2	1	4	3	0
		good	2	1	1	1	1	1	1	1	1	0	1	4	4	2	1	4	3	2
	poor	bad	2	1	0	1	1	1	1	1	2	1	0	4	4	3	1	4	3	0
		good	2	1	1	2	2	2	1	1	2	1	2	4	4	3	1	4	3	2
	moderate	bad	2	1	0	2	2	2	1	1	2	1	0	4	4	3	2	4	3	2
		good	2	2	1	2	3	3	2	1	2	3	2	4	4	3	3	4	3	2
	good	bad	2	1	0	2	2	2	3	1	3	1	0	4	4	4	2	4	3	0
		good	2	2	2	2	4	4	3	1	3	3	3	4	4	4	3	4	3	3
	high	bad	2	1	0	2	3	3	2	1	3	1	0	4	4	4	3	4	3	0
		good	2	2	2	2	4	4	4	1	3	3	4	4	4	4	4	4	3	4
large	bad	bad	3	2	0	2	1	1	1	3	2	1	0	4	4	2	1	4	4	0
		good	3	2	1	3	1	1	1	3	2	2	1	4	4	4	2	4	4	4
	poor	bad	3	2	0	3	2	2	2	3	3	1	0	4	4	4	2	4	4	1
		good	3	3	3	3	2	2	2	3	3	3	2	4	4	4	3	4	4	4
	moderate	bad	3	2	1	3	3	3	2	3	4	1	0	4	4	4	3	4	4	1
		good	3	3	3	4	3	3	4	3	4	4	3	4	4	4	3	4	4	4
	good	bad	3	3	1	3	3	3	2	3	4	2	1	4	4	4	4	4	4	1
		good	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4
	high	bad	3	4	1	3	4	4	2	3	4	2	1	4	4	4	4	4	4	1
		good	4	4	4	4	4	4	4	3	4	4	4	4	4	4	4	4	4	4

Appendix 3. Matrix for determination and assessment coastal seas' ecosystem services

		Provisioning services				Regulating and maintaining services					Cultural services						Abiotic services				
Ecological status	Shore type/Biome	Algae stock	Herbal biomass of coastal grasslands	Fish stock (commercial fishing)	Reed (material)	Habitat maintenance	Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Protected species and key species, natural habitats and maintenance of the balance between them	Natural sedimentation and transport of sediments, erosion regulation	Maintenance of hydrodynamics and flood risk mitigation	Environmental conditions suitable for recreation (by type)	Environmental conditions suitable for leisure fishing and hunting (by type)	Source of inspiration for creative activity	Opportunity for research	Opportunity for education	Natural symbols (spiritual sites, national symbols)	Environmental conditions suitable for the production of wind energy	Environmental conditions suitable for the production of hydrothermal energy	Environmental conditions suitable for navigation (incl. cooling water, bilge water etc.)	Environmental conditions suitable for the construction of ice roads	Mud supply (for therapy and agricultural purposes)
		P	P	P	P	R	R	R	R	R	C	C	C	C	C	C	Ab	Ab	Ab	Ab	Ab
Bad	Silt	1	3	1	3	4	1	2	2	4	4	1	3	2	3	2	1	4	1	2	2
	Till	1	3	1	3	4	1	2	2	4	4	1	3	2	3	2	1	4	1	3	3
	Gravel	1	0	1	0	0	1	1	2	3	2	1	2	2	3	3	1	4	1	2	3
	Sand	1	1	1	1	1	1	1	1	3	2	1	2	2	3	2	1	4	1	2	4
	Artificial	1	0	1	0	0	1	0	1	1	2	3	0	2	1	3	0	3	4	4	1
	Cliffed	1	0	1	0	0	1	1	1	3	4	1	2	3	3	3	2	3	2	3	0
	Coastal sea (benthal, pelagial)	0	0	1	0	0	1	1	0	depends	depends	2	1	2	4	1	0	0	2	4	4
	High sea (pelagial)	0	0	1	0	0	1	1	0	on bottom	on	2	1	2	4	0	0	4	0	4	4
	High sea (benthal)	0	0	0	0	0	1	0	0	geology 3-	bottom	2	1	2	4	0	0	4	0	4	4
Poor	Silt	2	4	2	3	4	2	2	2	4	4	1	4	2	4	3	2	4	1	2	2
	Till	2	4	2	3	4	2	2	2	4	4	2	3	2	4	3	2	4	1	3	3
	Gravel	2	0	2	0	0	2	2	1	3	2	1	3	2	4	3	2	4	1	2	3
	Sand	2	1	2	1	1	2	1	1	3	2	2	2	2	4	3	2	4	1	2	4
	Artificial	2	0	2	0	0	2	1	1	1	4	3	0	2	2	2	0	3	4	4	1
	Cliffed	2	0	2	0	0	2	1	1	3	4	3	2	4	4	3	3	3	2	3	0
	Coastal sea (benthal, pelagial)	1	0	2	0	0	2	2	1	depends on	depends on	3	2	2	4	2	0	0	2	4	4
	High sea (pelagial)	0	0	2	0	0	2	1	1	bottom	bottom	3	2	2	4	0	0	4	0	4	4
	High sea (benthal)	0	0	1	0	0	2	0	1	geology 3-4	geology 2-4	3	2	2	4	0	0	4	0	4	4
Moderate	Silt	4	4	3	4	4	3	2	3	3	3	3	3	3	4	4	3	4	1	2	3
	Till	4	4	3	4	4	3	2	3	3	3	3	4	3	4	4	3	4	1	3	3
	Gravel	4	0	3	0	0	3	2	2	2	2	2	3	3	4	3	3	4	1	2	3
	Sand	4	1	3	1	1	3	2	2	2	2	3	1	3	4	3	3	4	1	2	4
	Artificial	4	0	3	0	0	2	1	1	1	4	3	1	2	2	2	0	3	4	4	1
	Cliffed	4	0	3	0	0	3	2	2	2	4	3	3	3	4	3	4	3	2	3	0
	Coastal sea (benthal, pelagial)	4	0	3	0	0	3	2	2	depends on	depends on	3	3	3	4	3	0	0	2	4	4
	High sea (pelagial)	0	0	3	0	0	3	2	2	bottom	bottom	3	3	3	4	0	0	4	0	4	4
	High sea (benthal)	0	0	3	0	0	3	2	2	geology 3-4	geology 2-4	3	3	3	4	0	0	4	0	4	4
Good	Silt	4	4	4	4	3	4	3	4	3	3	4	4	4	4	4	3	4	1	2	3
	Till	4	4	4	4	3	4	3	4	2	2	3	4	4	4	4	4	4	1	3	4
	Gravel	4	0	4	0	0	4	3	3	2	1	2	3	3	4	3	3	4	1	2	3
	Sand	4	1	4	1	1	4	3	2	2	1	3	2	4	4	3	3	4	1	2	4
	Artificial	4	0	4	0	0	2	2	1	1	4	3	1	2	2	2	0	3	4	4	1
	Cliffed	4	0	4	0	0	4	2	3	2	4	3	4	4	4	4	4	3	2	3	0
	Coastal sea (benthal, pelagial)	4	0	4	0	0	4	3	3	depends on	depends on	3	3	4	4	4	0	0	2	4	4
	High sea (pelagial)	0	0	4	0	0	4	3	3	bottom	bottom	3	3	4	4	0	0	4	0	4	4
	High sea (benthal)	0	0	4	0	0	4	3	3	geology 3-4	geology 2-4	3	3	4	4	0	0	4	0	4	4
High	Silt	2	3	2	4	2	3	4	4	3	2	4	3	4	3	3	4	4	1	2	4
	Till	2	2	2	3	2	3	4	4	2	1	4	3	4	3	3	4	4	1	3	3
	Gravel	2	0	2	0	0	3	3	2	1	1	3	2	4	3	2	3	4	1	2	4
	Sand	2	0	2	0	0	3	2	2	1	1	4	2	4	3	2	4	4	1	2	4
	Artificial	2	0	2	0	0	2	2	1	1	4	4	1	3	2	1	0	3	4	4	1
	Cliffed	2	0	2	0	0	3	3	3	2	4	4	3	4	3	4	4	3	2	3	0
	Coastal sea (benthal, pelagial)	4	0	2	0	0	4	3	4	depends on	depends on	4	2	4	4	4	0	0	2	4	4
	High sea (pelagial)	0	0	2	0	0	4	3	4	bottom	bottom	4	2	4	4	0	0	4	0	4	4
	High sea (benthal)	0	0	2	0	0	4	3	4	geology 3-4	geology 2-4	4	2	4	4	0	0	4	0	4	4

Appendix 4. Indicators for monitoring ecosystem services of rivers, lakes and the coastal sea

Table 1. Monitoring indicators for lake ecosystem services

Service	Indicator (unit) (type: D, P, S, I, R)
Fish stock (commercial fishing)	Demand for fish (EUR/kg) (D); Amount of fish caught (t/ha/yr) (P); Estimation of fish stock - by species (t/yr) (S);Benefit resulting from realisation of catch (profit) (EUR/yr) (I); Fishing authorisations of fishing vessels (number) (R); Fishing quotas (t/yr) (R); Coastal fishing regulations (t/yr) (R); Number of fishing permits for fishermen (number) (R)
Surface water supply (drinking water)	Consumers of surface water (% of population) (D); Surface water extraction (percentage of water extraction in water balance (%)) (P); Wastewater influx (m^3) (P); Surface water quality (compliance with standard) (yes/no) (S); Expenses related to bringing drinking water up to standard (EUR/m^3) (I); Cost of drinking water (based on surface water) (EUR/m^3) (R)
Surface water for other purposes than drinking (by economic sector)	Water requirement according to sector (m^3/yr) (D); water extraction amount in sector (m^3/yr) (P); Adequate quantity of water (stable supply) (yes/no) (S); Special permits for water use (number/m^3) (R)
Reed (common reed)	Demand for common reed and its use (D); Reed storage (ha/yr) (P); Area of (usable) reeds (ha) (S); Benefit (profit) resulting from realisation of reed stock (EUR/a) (I); Area-specific regulations in nature reserves (% of whole area) (R)
Habitat maintenance	Proportion of natural land in the catchment area in the vicinity of water body (%) (D); Algal bloom (yes/no; percentage) (P); Presence of indicator species (yes/no) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); The number and extent of types of habitat (number; ha) (S); The number and amount of species (number; species) (S); The number and percentage of endangered species (number; %) (S); Change in ecological status (trend) (I); Change in chemical status (trend) (I); Clogging (yes/no) (I); Restoration and creation of spawning areas (ha, amount (R); Programmes of measures (Water Framework Directive; WFD) (number of programmes; effectiveness of measures) (R); Opening of lake inlets and outlets, removal of sediments; mowing of flora (m3, ha) (R)
Habitat maintenance of protected species	Decrease in the number of protected species (%) (P); Number of protected species (species/ha) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Buildings, infrastructure, agricultural land in the catchment area (%) (I); Change in ecological status (trend) (I); Change in chemical status (trend) (I); Nature reserve area designated for protected aquatic ecosystem species (ha, %) (R)
Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Change in carrying capacity (from general P catchment area mg/l) (P); Load from point source pollution (population equivalent (PE)) (P); Load from diffuse pollution (population equivalent (PE)) (P); Volume of water (m^3) (S); Water hardness (HCO3 mg/l) (S); Nutritional status (trophic classes) (S); General P (mg/l) (S); General N (mg/l) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Buildings, infrastructure, agricultural land in the catchment area (%) (I); Change in ecological status (trend) (I); Change in chemical status (trend) (I); Regulation of lake inlets and outlets, removal of sediments; mowing of flora (yes/no) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Maintenance of hydrodynamics and flood protection	Economic activity in areas exposed to flood risk (number of households) (D); Damage to land cover types that maintain outlet (e.g. building up of areas) (ha; %) (P); Extent of catchment area (ha) (P); Percentage of modified coastal area (%) (P); Difference from nominal water status (%) (S); Water exchange (times a year) (S); Regulation of water levels (yes/no) (R); Investments made for maintenance of water quantity (in the catchment area?) (EUR/a) (R); Protection and restoration of land cover types that maintain outlet (ha; %) (R)
Environmental conditions suitable for recreation (by type - both passive and active rest/sport)	Existence of infrastructure and presence of recreational service providers (yes/no; number) (D); Protection (restrictions, incl. nature conservation and other, and trampling index) (yes/no) (P); Number of water and ice sports practitioners (people) (S); Recording (nature photography and other fine arts) (yes/no) (S); Number of popular sites and sites with popular scenic views (birdwatching and nature viewing spots) (yes/no) (S); Number of days safe for swimming (flag colour) (days) (S); Number of official recreational sites in the vicinity of the water body (number) (S); Change in the number of holidaymakers (people/yr) (I); Change in beach/swimming area proportion of coastline (%) (I); Number of days per year with precipitation (days/yr) (I); Investments made for creation and maintenance of infrastructure (EUR/yr) (R)
Environmental conditions suitable for leisure fishing and hunting (by type)	Number of fishing authorisations (fishing permits, hunter's licences etc.) (number) (D); Conservation (catch limitation) (yes/no) (P); Amount of fish caught (t/ha/yr) (P); CPUE (catch per unit effort) per net (kg/number per unit) (S); Amount of fishing spots (number) (S); Presence of predatory fish (northern pike, perch) (yes/no) (I); Re-population/enrichment of water body (number of fish) (species; kg; EUR) (R); Popularity of fishing spots in the media (amount of results in search engines) (R)
Catching of crayfish	Number of permits for catching of crayfish (number) (D); Amount of crayfish caught (t/ha/yr) (P); CPUE (number per trap night) (S); Re-population/enrichment of water body (number of crayfish) (species/water body; kg) (R)
Opportunity for research	Unresolved issues regarding the ecosystem (yes/no) (D); Funding of science (% of GDP) (P); Scientific research (number) (S); Existence of monitoring sites for water bodies (yes/no) (S); Developing methods for restoration/maintenance of ecosystem on the basis of research (yes/no) (I); Funding of state monitoring (EUR) (R); Funding of scientific research (for project) (EUR) (R)
Opportunity for education	Infrastructure (yes/no; number) (D); Inadequate funding of education (% of GDP) (P); Number of study trips related to water body (number of participants) (number) (S); People active in and studying natural sciences, environmental awareness (people) (I); Funding of outdoor study projects (number; EUR) (R)
Source of inspiration for creative activity	Art camps (existence, number) (yes/no; number) (D); Disappearance/ruining of sites with "popular/scenic views" (yes/no) (P); Nature photography (and other fine arts) (yes/no) (S); Abundance of sites with "popular/scenic views" (number) (S); Accessibility (yes/no) (I); Plans, conservation (yes/no) (R)
Natural symbols (spiritual sites, national symbols)	Heritage and legends related to water body (yes/no; number) (D); Number of carriers of hereditary culture (people) (D); Economic activity (yes/no) (P); Existence of natural symbols (yes/no; number) (S); Disappearance of natural symbols (yes/no; number) (I); Investments made for the conservation of heritage (accessibility, signs, etc.) (EUR) (R); Institutions established for the conservation of natural symbols (museums etc.) (number) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Mud supply (for therapy and agricultural purposes)	Number of consumers (people/yr) (D); Popularisations (number/yr) (D); Existence and extent of active or passive supply (ha; %) (S)
Environmental conditions suitable for the production of hydro-thermal energy	Increase in fuel expenses/profitability (EUR) (D); Restrictions induced by environmental protection (yes/no) (P); Installed heat pumps (number) (S); Modification of hydrological characteristics of water body (yes/no) (I); Subsidies (yes/no) (R)
Environmental conditions suitable for water transport	Number of harbours (incl. number of landing places, ramps) (number) (D); Navigation (ships/24h) (P); Number of (registered) boats (number) (P); Number of people operating watercraft (people) (S); Change in the number of (registered) watercraft (trend) (I); Watercraft speed limits (yes/no) (R); Investments made for the construction of harbours/boat moorings (EUR) (R)

Table 2. Monitoring indicators for river ecosystem services

Service	Indicator (unit) (type: D, P, S, I, R)
Fish stock (commercial fishing)	Demand for fish (EUR/kg) (D); Amount of fish caught (t/yr) (P); Estimation of fish supply - by species (t/yr) (S); Fishing quotas (t/yr) (R); Number of fishing permits for fishermen (no) (R)
Surface water supply (drinking water)	Consumers of surface water (% of population) (D); Surface water extraction (percentage of water extraction in water balance (%)) (P); Wastewater influx (m^3) (P); Surface water quality (compliance with standard) (yes/no) (S); Expenses related to bringing drinking water up to standard (EUR/m^3) (I); Cost of drinking water (based on surface water) (EUR/m^3) (R)
Surface water for other purposes than drinking (by economic sector)	Water requirement according to sector (m^3/yr) (D); Water extraction amount in sector (m^3/yr) (P); Adequate quantity of water (stable supply) (yes/no) (S); Special permits for water use (number/m^3) (R)
Habitat maintenance	Proportion of natural land in the catchment area in the vicinity of water body (%) (D); Land improvements and infrastructures in the catchment area (yes/no) (P); Barrage (man-made) (number; height; area/volume of reservoir) (P); Straightening and deepening of water bodies (length, depth m) (P); Hydro-morphological index of watercourse (status classes) (S); Abundance of species (fish, major plants and invertebrates) (number) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Salmonid and shellfish habitats (number) (S); Amount/extent of foreign species (number of species) (S); Change in the spread of foreign species (trend) (I); Change in the biodiversity of species (fish, major plants and invertebrates) (trend) (I); Change in ecological status (trend) (I); Change in chemical status (trend) (I); Programmes of measures (Water Framework Directive) (number of programmes; effectiveness of measures) (R); Restoration and creation of spawning areas (ha; no) (R)
Habitat maintenance of protected species	Artificial modification of hydro-morphological parameters (yes/no; m/km) (P); Mining activities altering hydro-morphology and water regime (sand, gravel, peat, coal) (yes/no) (P); Barrage (man-made) (number; height; (m)) (P); Ditch drainage of catchment area (m/km^2) (P); High levels of groundwater abstraction (m^3/yr) (P); Number of protected species (species/ha) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Change in ecological status (trend) (I); Change in chemical status (trend) (I); Change in the number of buildings, infrastructures and amount of agricultural land in the

Service	Indicator (unit) (type: D, P, S, I, R)
	catchment area (%) (I); Percentage of protected areas (ha/m; %) (R); Protected area designated for protected species of the aquatic ecosystem (ha; %) (R)
Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Artificial modification of hydro-morphological parameters (yes/no; m/km) (P); Load from point source pollution (population equivalent (PE)) (P); Load from diffuse pollution (kg/ha) (P); Number of wastewater outfalls (no; m^3/24h) (P); Phosphate concentration in water (general P catchment area mg/l) (S); Nitrate concentration in water (general N catchment area mg/l) (S); Ecological status (according to the WFD) (status class) (S); Chemical status (according to the WFD) (status class) (S); Change in ecological status (according to the WFD) (trend) (I); Change in chemical status (according to the WFD) (trend) (I); Existence of buildings, infrastructure and agricultural land in the catchment area(%) (I); Number of water use permits (number) (R); Norms for the status of aquatic environment (yes/no) (R); Investments made for maintaining water quality/construction of wastewater treatment infrastructure (in catchment area) (EUR/a) (R)
Maintenance of hydrodynamics and flood protection	Economic activity in areas exposed to flood risk (ha; %; number of residents) (D); Damage to land cover types that maintain outlet (%; ha) (P); Flow amount (m^3/year (volume); (layer mm/yr) (S); Hydro-morphological parameters of flood plains (level of ditch drainage) (fall m; area ha) (S); Hydraulic cohesion index of the bed of the watercourse and flood plains (numeric value) (S); Frequency and extent of floods; Water level (ha; m) (S); Protection and restoration of land cover types that maintain outlet (%; ha) (R); Investments made for maintenance of water quality (catchment area) (EUR/a) (R)
Environmental conditions suitable for recreation (by type - both passive and active rest/sport)	Existence of infrastructure and presence of recreational service providers (yes/no; number) (D); Protection (restrictions, incl. nature conservation and other, and trampling index) (yes/no) (P); Recording (nature photography and other fine arts) (yes/no) (S); Number of popular sites and sites with popular scenic views (birdwatching and nature viewing spots) (yes/no) (S); Number of days safe for swimming (flag colour) (days) (S); Number of water sports practitioners (people) (S); Number of official recreational sites in the vicinity of the water body (number) (S); Change in the number of holidaymakers (people/yr) (I); Change in the beach/swimming area proportion of coastline (%) (I); Investments made for creation and maintenance of infrastructure (EUR/yr) (R)
Environmental conditions suitable for leisure fishing and hunting (by type)	Number of fishing authorisations (fishing permits, hunter's licences etc.) (number) (D); Amount of fish caught (t/ha/yr) (P); Conservation (catch limitation, incl. nature conservation and other (stock-based) (yes/no) (P); Number of fish species, number of species specific to a certain location in the river (number) (S); Abundance of fishing spots (number) (S); Presence of predatory fish (northern pike, perch) (yes/no) (I); Re-population/enrichment of water body (number of fish) (species; kg; EUR) (R); Popularity of fishing spots in the media (amount of results in search engines) (R)
Catching of crayfish	Number of permits for catching of crayfish (number) (D); Amount of crayfish caught (t/ha/yr) (P); CPUE (number per trap night) (S); Re-population/enrichment of water body (number of crayfish) (species/water body; kg) (R)
Opportunity for research	Unresolved issues regarding the ecosystem (yes/no) (D); Funding of science (% of GDP) (P); Scientific research (number) (S); Existence of monitoring sites for water bodies (yes/no) (S); Developing methods for restoration/maintenance of ecosystem on the basis of research (yes/no) (I); Funding of state monitoring (EUR) (R); Funding of scientific research (for project) (EUR) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Opportunity for education	Infrastructure (yes/no; number) (D); Inadequate funding of education (% of GDP) (P); Number of study trips related to water body (number) (S); People active in and studying natural sciences, environmental awareness (people) (I); Funding of outdoor study projects (number; EUR) (R)
Source of inspiration for creative activity	Art camps (existence, number) (yes/no; number) (D); Disappearance/ruining of sites with "popular/scenic views" (yes/no) (P); Nature photography (and other fine arts) (yes/no) (S); Abundance of sites with "popular/scenic views" (number) (S); Accessibility (yes/no) (I); Plans, conservation (yes/no) (R)
Natural symbols (spiritual sites, national symbols)	Heritage and legends related to water body (yes/no; number) (D); Number of carriers of hereditary culture (people) (D); Economic activity (yes/no) (P); Existence of natural symbols (yes/no; number) (S); Disappearance of natural symbols (yes/no; number) (I); Investments made for the conservation of heritage (accessibility, signs, etc.) (EUR) (R); Institutions established for the conservation of natural symbols (museums etc.) (number) (R)
Environmental conditions suitable for the production of hydro-thermal energy	Policies/price of electricity (EUR) supporting renewable energy (D); Requirements of the Directive (salmonid river) (yes/no; number) (P); Number of hydro-electric power plants, production amount (number; kW/h) (S); Subsidies (yes/no; number) (R)
Environmental conditions suitable for water transport	Number of harbours/moorings (incl. number of landing places, ramps) (number) (D); Use of watercraft (navigation) (P); Number of people operating watercraft (people) (S); Number of (registered) watercraft (number) (P); Change in the number of (registered) watercraft (trend) (I); Watercraft speed limits (yes/no) (R); Investments made for the construction of harbours/boat moorings (EUR) (R)

Table 3. Monitoring indicators for marine ecosystem services

Service	Indicator (unit) (type: D, P, S, I, R)
Algae stock	Number of people applying for seaweed collection permits (number) (D); Amount of collected seaweed (kg/yr) (P); Biomass of algae stock (t/yr) (S); Benefits (profit) from the use of seaweed (EUR/yr) (I); Quota for algae stock use (kg/yr) (R); Violation of the procedure established for the use of quota (number/yr) (R)
Herbal biomass of coastal grasslands	Demand for beef (buying-in price) (EUR) (D); Number of livestock (species/ha) (P); Grass production (t/ha/yr) (S); Change in production (t/ha/yr) (I); Total amount of subsidies and the extent of subsidised area (EUR/ha) (R)
Fish stock (commercial fishing)	Demand for fish (EUR/kg) (D); Ratio between catch and biomass index (catch/biomass index) (P); Contaminants in fish (micrograms/kg) (P); Biomass indexes by fish species (biomass index) (S); Benefit (profit) from the realisation of catch (EUR/yr) (I); Fishing permits for fishing vessels (number) (R); Fishing quotas (t/yr) (R); Coastal fishing regulations (t/yr) (R); Fishing permits for fishermen (number) (R)
Reed (common reed)	Demand for common reed and its use (D); Reed storage (ha/yr) (P); Area of (usable) reeds (ha) (S); Benefit (profit) resulting from realisation of reed stock (EUR/a) (I); Area-specific regulations in nature reserves (% of whole area) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Habitat maintenance	Percentage of environmental expenses in GDP (%) (D); Extent of shipping routes and navigation intensity (km2 (%); number) (P); Fishing areas and intensity (km2 (%); number) (P); Sea floor integrity: extent of sea floor significantly disrupted or permanently modified by human impact (km2; %) (P); Number and extent of types of habitat (number; ha) (S); Number/abundance of species (number; species) (S); Number and percentage of endangered species (number; %) (S); Existence and extent of ice cover (yes/no; percentage) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Spawning areas (ha; %) (S); Change in biological diversity and direction of change (need for different habitats) (trend) (I); Change in ecological status (according to the WFD) (trend) (I); Change in chemical status (according to the WFD) (trend) (I); Programmes of measures (no.) (R); Marine protected areas (ha; %) (R); Marine spatial planning (ha; %) (R)
Habitat maintenance of protected species	Percentage of environmental expenses in GDP (%) (D); Extent of shipping routes and navigation intensity (km2 (%); number) (P); Fishing areas and intensity (km2 (%); number) (P); Number and extent of types of habitat of protected species (number; ha) (S); Number/abundance of protected species (number; species) (S); Presence of protected species (yes/no; percentage) (S); Ecological status (according to the WFD) (status classes) (S); Chemical status (according to the WFD) (status classes) (S); Spawning areas of protected species (ha; %) (S); Change in the biological diversity of protected species and direction of change (need for different habitats) (trend) (I); Change in ecological status (according to the WFD) (trend) (I); Change in chemical status (according to the WFD) (trend) (I); Proportion of protected area (ha; %) (R); Nature reserve area designated for protected aquatic ecosystem species (ha; %) (R)
Natural sedimentation and transport of sediments, erosion regulation	Percentage of environmental expenses in GDP (%) (D); Sedimentation of heavy metals and POP substances (t/ha/yr) (P); Increase in the percentage of artificial coastal structures (% of total coastline length) (P); Nutrient sedimentation (t/ha/yr) (S); Displacement, dredging and dumping of eroded areas (m3/yr) (S); Proportion of protected areas (ha; %) (R)
Maintenance of natural water (natural water quality, wastewater dilution, self-purification)	Percentage of environmental expenses in GDP (%) (D); Sedimentation of heavy metals and POP substances (t/ha/a) (P); Load from point source pollution (population equivalent (PE)) (P); Load from diffuse pollution (population equivalent (PE)) (P); Wastewater inlet (m3) (P); Chemical status (according to the WFD) (status classes) (S); Reed area and percentage of reed-hemmed coastline (ha; %) (S); Nutritional status (trophic classes) (S); Ecological status (according to the WFD) (status classes) (S); Nutrient sedimentation (t/ha/yr) (I); Change in ecological status (according to the WFD) (trend) (I); Change in chemical status (according to the WFD) (trend) (I); Reduction of pollution load (t/yr) (R); Removal of waste and contaminated sediments (t/ha/yr) (R); Investments made for maintaining water quality/construction of wastewater treatment infrastructure (in catchment area) (EUR/a) (R)
Maintenance of hydrodynamics and flood protection	Percentage of environmental expenses in GDP (%) (D); Types of land use of potentially flooded areas (%; map) (P); Types of land use in catchment area (%; map) (P); Water level above zero (m above sea level) (P); Frequency and extent of floods; Water level (number; ha; metres) (S); Coastal zone type (type) (S); Change in the morphology of coastal areas (height/depth change, m) (I); Building ban regulation (yes/no) (R); Raising the height of coast (m) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Environmental conditions suitable for recreation (by type - bot passive and active rest/sport)	Existence of infrastructure and presence of recreational services providers (yes/no; number) (D); Protection (all sorts of restrictions, incl. nature conservation and other, as well as trampling index) (yes/no) (P); Recording (nature photography and other fine arts) (yes/no) (S); Number of popular sites and sites with "popular scenic views" (birdwatching and nature viewing spots) (yes/no) (S); Number of days safe for swimming (flag colour) (days) (S); Number of water and ice sports practitioners (people) (S); Number of official recreational sites in the vicinity of the water body (number) (S); Change in the number of holidaymakers (people/yr) (I); Change in the beach/swimming area proportion of coastline (%) (I); Investments made for creation and maintenance of infrastructure (EUR/yr) (R); Construction of recreational areas (ha; %) (R)
Environmental conditions suitable for leisure fishing and hunting (by type)	Number of fishing authorisations (fishing permits, hunter's licences etc.) (number (D); Conservation (fishing restrictions) (yes/no) (P); Number of storm-free days, Number of days with ice (number) (S); Investments made for maintenance and restoration of fish and game populations (EUR/yr) (R)
Opportunity for research	Unresolved issues regarding the ecosystem (yes/no) (D); Funding of science (% of GDP) (P); Scientific research (number) (S); Existence of monitoring sites for water bodies (yes/no) (S); Developing methods for restoration/maintenance of ecosystem on the basis of research (yes/no) (I); Funding of state monitoring (EUR) (R); Funding of scientific research (for project) (EUR) (R)
Opportunity for education	Infrastructure (yes/no; number) (D); Inadequate funding of education (% of GDP) (P); Number of study trips related to water body (number) (S); People active in and studying natural sciences, environmental awareness (people) (I); Funding of outdoor study projects (number; EUR) (R)
Source of inspiration for creative activity	Art camps (existence, number) (yes/no; number) (D); Disappearance/ruining of sites with "popular/scenic views" (yes/no) (P); Nature photography (and other fine arts) (yes/no) (S); Abundance of sites with "popular/scenic views" (number) (S); Accessibility (yes/no) (I); Plans, conservation (yes/no) (R)
Natural symbols (spiritual sites, national symbols)	Number of carriers of hereditary culture (people) (D); Economic activity (yes/no) (P); Existence of natural symbols (yes/no; number) (S); Disappearance of natural symbols (yes/no; number) (I); Investments made for the conservation of heritage (accessibility, signs, etc.) (EUR) (R); Institutions established for the conservation of natural symbols (museums etc.) (number) (R)
Mud supply (for therapy and agricultural purposes)	Number of consumers (people/yr) (D); Popularisations (number/yr) (D); Existence and extent of active or passive supply (ha; %) (S)
Environmental conditions suitable for the production of wind energy	Cost of electricity (EUR) (D); Renewable energy planning (yes/no) (D); Environmental regulations (yes/no) (P); Availability of subsidy, power requirement (yes/no) (P); Number of wind turbines, amount of energy produced MW/h (MW/h) (S); Benefit (profit) from marine energy production (EUR/a) (I); Plans, identification of suitable areas for the placement of wind turbines (number/area/planned MW/h) (R)
Environmental conditions suitable for the production of hydro-thermal energy	Increase in fuel expenses /profitability (EUR) (D); Renewable energy planning (yes/no) (D); Environmental regulations (yes/no) (P); Availability of subsidy (yes/no) (P); Installed heat pumps (number) (S); Benefit (profit) from marine heat production (EUR/a) (I); Plans, identification of suitable areas for the generation of hydro-thermal energy (number/area/planned MW/h) (R)

Service	Indicator (unit) (type: D, P, S, I, R)
Environmental conditions suitable for water transport	Number of ramps and small harbours (number) (D); Number of transit ports, volume of goods hauled (number; t/yr) (D); Navigation (ships /24h) (P); Number of people operating watercraft (people) (P); Marine protected areas (ha; %) (P); Number of (registered) boats (number) (S); Port profits (EUR/yr) (I); Regulation/planning of navigation (yes/no) (R)
Environmental conditions suitable for the construction of ice roads	Number of road users (people) (D); Navigation/crossing with shipping routes (ships/24h; yes/no) (P); Number, length (number; km) (S); Number of ice road accidents (number) (I); Planning of use and construction of ice roads (yes/no) (R); Regulation of navigation (yes/no) (R)

Appendix 5. Methods for assessing economic value and the advantages and disadvantages of these methods

Methods for assessing economic value	Aspect of market value assessed	Assessed ecosystem services	Advantages of method	Disadvantages of method
Assessment based on market price	Direct and indirect use	Ecosystem services providing input for market-based products such as timber, fish, genetic information	Market-based data easily accessible and concrete	Limited to tradable ecosystem services
Assessment based on production inputs	Indirect use	Environmental services as input for production, e.g. effect of air and water quality on agricultural and forestry products	Market-based data easily accessible and concrete	Large amounts of data; often no data on factors affecting production, connections may be incomprehensible
Expenditure-based (preventive, substituting, regenerative expenditure) assessment	Direct and indirect use	Depends on market-based solutions related to the ecosystem service, e.g. artificial flood protection systems comparable to buffer capacity of natural wetlands; comparison of the natural water filtration service to the value of damage done by polluted water	Market-based data easily accessible and concrete	Possible over-estimation of real value
Assessment based on real estate prices	Direct and indirect use	Ecosystem services contributing to air quality, scenic views, landscapes, serenity i.e. features appreciated by potential buyers of real estate	Based on market data, relatively concrete	Very large amouts of data, limited to services affecting real estate
Assessment based on transport costs	Direct and indirect use	All ecosystems supporting recreational activities	Based on monitoring	Mostly limited to the assessment of recreational value. Problematic if a trip has more than one purpose

Assessment of random sampling of use	Direct and indirect use	All ecosystems supporting recreational activities	Based on monitoring	Limited to the assessment of value in use
Contingent valuation	Value in use and non-use	All ecosystem services	Allows for the assessment of value in use and non-use	Time-consuming, results sensitive to composition of the questionnaire
Discrete choice method	Value in use and non-use	All ecosystem services	Allows for the assessment of value in use and non-use	Similar to those of the previous method; allows for a more detailed assessment of ecosystem effects; bias reduced by use of statistical methods
Benefit transfer	Direct and indirect use	All ecosystem services	Easy to use, fast results	Accuracy of results depends on the accuracy of conducted survey