Sveriges lantbruksuniversitet
Swedish University of Agricultural Sciences

Institutionen för Akvatiska resurser
Department of Aquatic Resources

PM
2018-02-09

SLU ID: SLU.aqua.2017.4.2-207
HaV IDs: 1956-17 and 2019-17

Relationships between human activities and marine ecosystem services

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Introduction and background

Human activities have fundamentally altered the structure and function of many marine ecosystems worldwide (Halpern et al. 2008). These activities have diverse and widespread effects on ecosystem services; i.e., the benefits which people get from ecosystems, and which concurrently serve as preconditions of human activities related to the sea (Bryhn et al., 2015). The purpose of this work is to develop approaches for analysing the relationships between the human use of marine waters and ecosystem services, focusing on the Swedish coast as well as the entire Baltic Sea. We also aim at providing an updated assessment of pressures on ecosystem services along the Swedish coastline, building on earlier work (Bryhn et al. 2015). The central goal is to examine how different activities impose impact and are dependent on (to what extent they use) ecosystem services. The linkages are explored using quantitative data where possible and expert judgements when quantitative data are lacking. Basically, the DPSIR (***Driver – Pressure – State change – Impact – Response***) approach (Fig. 1) is followed. DPSIR is a framework for describing causal relationships in the interaction between the society and the environment. It has been widely discussed and debated but has proven to work well at many different occasions as it can be understood by various people from scientists and politicians to local stakeholder groups (Atkins et al. 2011, Patrício et al. 2016). For the purposes of this work, the first four letters "DPSI" are of most interest. Here, D represents Drivers (focusing on secondary drivers as human activities), P stands for the Pressures from human activities (acting on the ecosystem), S stands for State (as the changes imposed by pressures on ecosystem components) and finally, I stands for Impact on ecosystem services (Atkins et al. 2011). Note that this report uses activities and drivers (D) as synonyms.

List of human activities, pressures and ecosystem services

For the linking of ecosystem services to human activities, we have used the activities listed in Annex III of the Marine Strategy Framework Directive (MSFD) which have deemed relevant for the Baltic Sea region (HELCOM 2017; Table 1), and the Swedish national tool to support marine spatial planning; Symphony. The human activities (drivers) that give rise to pressures on ecosystems are defined and listed somewhat differently in MSFD Annex III and in Symphony. The MSFD pressures are shown in Fig. 2. The pressures used in Symphony are linked directly to human activities, and are listed in Table 2.

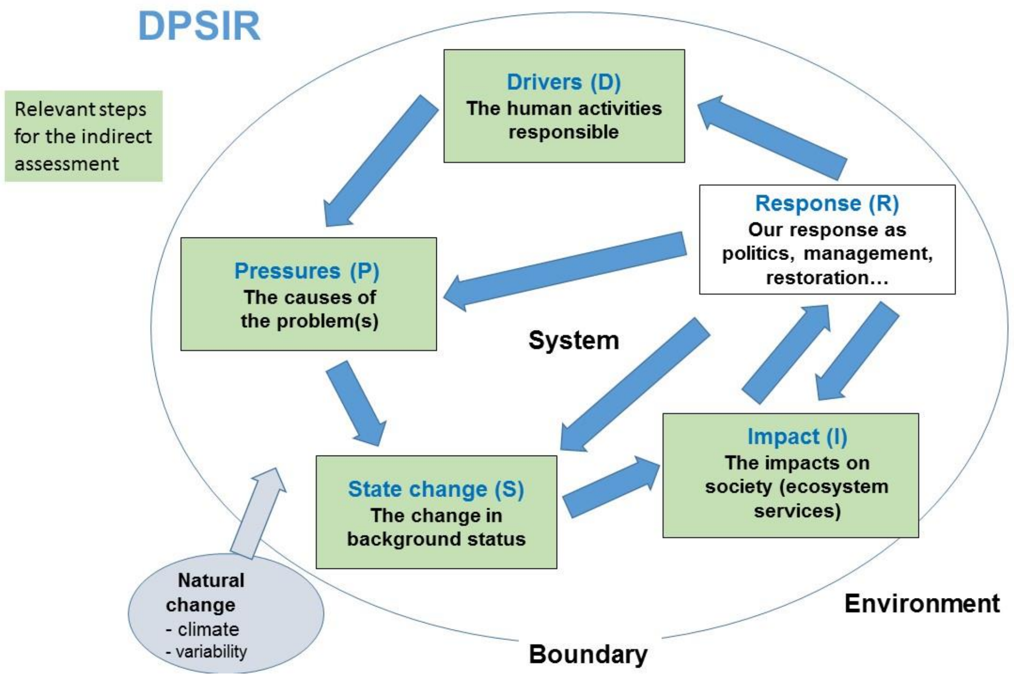

Figure 1. *The DPSIR-cycle as a framework for describing interactions between the society and the environment (from Atkins et al. 2011). The focus of this work is on compartments D, P, S and I.*

Table 1. *Human activities (Drivers) relevant for the study area and listed in Annex III in the Marine Strategy Framework Directive.*

Theme	MDFD Secondary Drivers / Human Activities
Physical restructuring of rivers, coastline or seabed (water management)	Land claim
	Restructuring of seabed morphology, including dredging and depositing of materials
Extraction of non-living resources	Extraction of minerals (rock, metal ores, gravel, sand, shell)
Production of energy	Renewable energy generation (wind, wave and tidal power), including infrastructure
	Nuclear power (uptake and discharge of cooling water)
	Transmission of electricity and communications (cables)
Extraction of living resources	Fish and shellfish harvesting (professional)
	Hunting and collecting for other purposes
Cultivation of living resources	Aquaculture — marine, including infrastructure
	Agriculture
	Forestry
Transport	Transport — infrastructure
	Transport — shipping
Urban and industrial uses	Urban uses
	Industrial uses
	Waste treatment and disposal
Tourism and leisure	Tourism and leisure infrastructure (including marinas)
	Tourism and leisure activities (including boating)
	Fish and shellfish harvesting (recreational)
Security defense	Security/defense Military operations
Education and research	Research, survey and educational activities
Other co-acting	Eutrophication
	Toxic pollution
	Climate change CO2, temperature and salinity

With regard to ecosystem services, a number of different classification systems exist that categorize ecosystem services, developed at the international and EU level, as well as in individual countries (Böhnke-Heinrichs et al. 2013, Hasler et al. 2016, Ivarsson et al. 2017). These categorizations have been developed for different purposes, and are often intended to be applicable to all ecosystem types (terrestrial, freshwater and marine) in comparable manners to support assessments. For the purposes of the current work, we have for used the list of ecosystem services presented in Bryhn et al. (2015), who have earlier assessed the status and pressures of Swedish marine ecosystem services. The project has not aimed at re-assessing the list, but has included more human activities and provided assessments at a somewhat more refined scale with regard to the impact of human activities on ecosystem services. The ecosystem services and their status (poor, moderate and good) as assessed by Bryhn et al. (2015) for different parts of the Swedish marine economic zone is presented below (Table 3). The letters preceding each ecosystem services indicate their grouping. In this respect, S stands for Supporting, R stands for Regulating, P stands for Provisioning and C stands for Cultural ecosystem services. The supporting ecosystem services Food web dynamics and Habitat were in poor conditions along the Swedish coast, whereas the provisioning ecosystem service Food was in poor condition in the Baltic proper and in Kattegat/Skagerrak (but in good condition in the Gulf of Bothnia) and the provisioning ecosystem service Raw material was in poor condition in Kattegat/Skagerrak. All other ecosystem services were in either moderate or good condition along the Swedish coast according to that assessment (Bryhn et al. 2015). The ecosystem services used in the current work are the same ones as in Bryhn et al. (2015) and in the left column of Table 3.

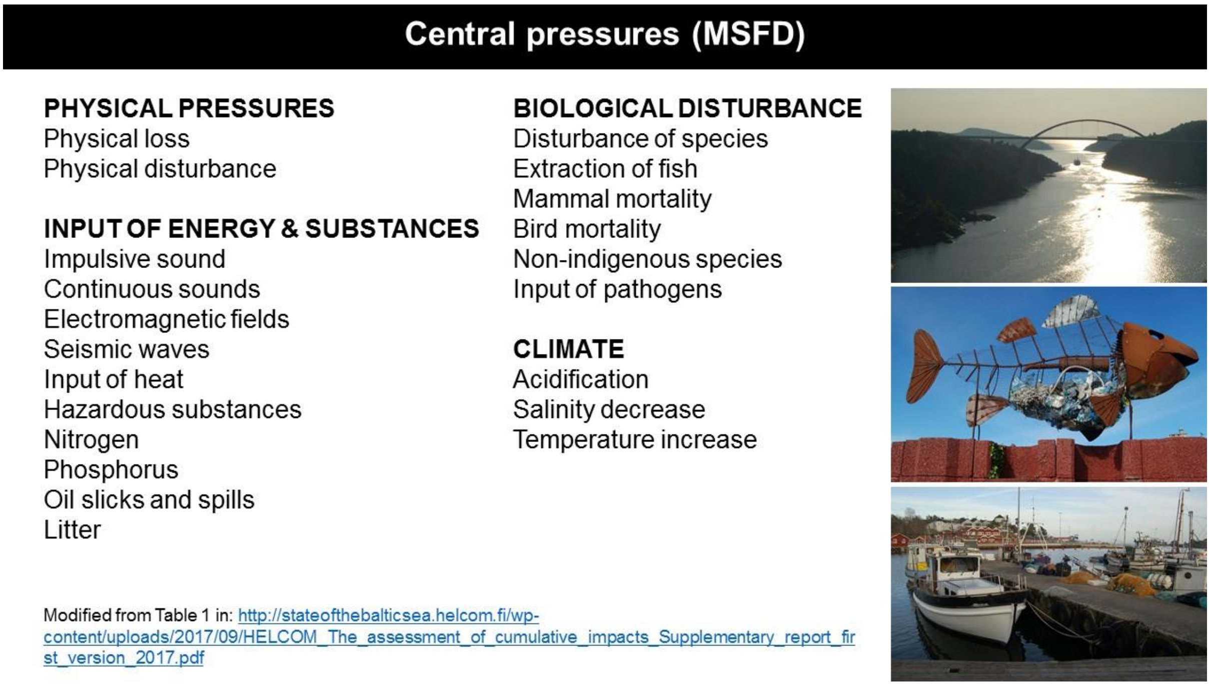

Figure 2. *Pressures relevant for the study area as presented in Annex III in the Marine Strategy Framework Directive.*

Establishing relationships between activities and ecosystem services

For assessing the relationships between human activities and marine ecosystem services, we have developed two types of methods: the direct (DI) method and the indirect (DPSI) method which will be described below. The direct/DI-method goes straight from human activities to estimating their impact on ecosystem services using an expert evaluation. This method uses the activities/pressures from Annex III in the Marine Strategy Framework Directive (Table 1) with the addition of a number of background drivers (caused by part human activities) such as eutrophication, toxic compounds and variables related to climate change. The indirect/DPSI-method, in turn, makes use of existing knowledge on links between activities/pressures to ecosystem components and is developed further from there onto assessing relationships between ecosystem components and ecosystem services.

The direct/DI-method

The direct (Driver-Impact, DI) method is dependent on expert judgment for assessing the links between human activities and ecosystem services. The method is a further development of the one used in a previous assessment of marine ecosystem services in Sweden (Bryhn et al. 2015), but comprises more activities and a more refined assessment scale. The estimated level of (negative) impact of each activity on each ecosystem service is evaluated and is given a score on a scale of 0–5, where 5 represents the highest impact and 0 no impact (see Table 4). In the current work, this was applied as a consensus assessment between the four scientists from SLU Aqua authoring this report. When estimating the scores, it was looked at the table from both of two perspectives: row by row, i.e. assessing each human activity at a time (in rows) in relation to all ecosystem services (in columns), and assessing each ecosystem service (in columns) in relation to all human activities (in rows). This was done in this way in order to focus on evaluating the relative strength of impact for each cell in comparison to all other cells, and so that all ecosystem services and human activities are included in the same evaluation. The score considers both the intensity/strength of the pressure and its geographical extent. This means that a pressure that may be strong, but very local, is given a relatively low score, e.g. pressure from aquaculture in Sweden (very restricted activity geographically), whereas an activity that may have a weaker impact, but is geographically extended may get a relatively high score, e.g. noise from shipping traffic.

Table 2. *Activities/pressures used for the impact evaluation in Symphony*

Abrasion, Bottom trawling
Abrasion, Dredging
Anoxia, Background
Avoidance, Windpower
Bird hunt
Boating, Noise
Boating, Pollution
Catch, Bottom trawling
Catch, Gillnet
Catch, Pelagic trawl
Electromagnetic fields
Explosion, PM
Explosion, SPL
Ghost nets
Habitat loss, Mining
Habitat loss, Coastal Exploitation
Habitat loss, Dumping
Habitat loss, Fish farm
Habitat loss, Mussel farming
Infrastructure
Macroplastics
Microplastics
Nitrogen, Background
Nitrogen, Fish farming
Noise 125Hz, Shipping
Noise 125Hz, Wave power
Noise 125Hz, Wind power
Noise 2000Hz, Shipping
Ocean Acidification 2050
Oil spill 2 knots, Shipping
Oil spill 2 knots, Wreck
Pathogens, Fish farm
Pathogens, Treatment plants
Phosphorous, Background
Temp. increase, Summer 2050
Temp. increase, Winter 2050
Toxic Metal, Background
Toxic Metal, Fibre banks
Toxic Metal, Mercury dump
Toxic Metal, Military
Toxic, Mine Risk
Toxic, Munition
Toxic Synthetic, Background
Toxic Synthetic, Harbor
Toxic Synthetic, Industry
Toxic Synthetic, Treatment plants
Turbidity, Bottom trawl
Turbidity, Dredging
Turbidity, Mining
Turbidity, Shipping

Table 3. *Marine ecosystem services and their evaluated status in the Swedish marine economic zone (from Bryhn et al. 2015).*

Ecosystem service	Kattegat and Skagerrak	Baltic Proper	Gulf of Bothnia
S1: Biogeochemical cycling	Moderate	Moderate	Moderate
S2: Primary production	Moderate	Moderate	Good
S3: Food web dynamics	Poor	Poor	Poor
S4: Biodiversity	Moderate	Moderate	Moderate
S5: Habitat	Poor	Poor	Good
S6: Resilience	Moderate	Moderate	Moderate
R1: Climate and atmospheric regulation	Moderate	Moderate	Moderate
R2: Sediment retention	Moderate	Moderate	Good
R3: Regulation of eutrophication	Moderate	Moderate	Good
R4: Biological regulation	Moderate	Moderate	Good
R5: Regulation of toxic substances	Moderate	Moderate	Moderate
P1: Food	Poor	Poor	Poor
P2: Raw material	Poor	Moderate	Good
P3: Genetic resources	Good	Good	Good
P4: Chemical resources	Good	Good	Good
P5: Ornamental resources	Good	Good	Good
P6: Energy	Good	Good	Good
C1: Recreation	Moderate	Moderate	Moderate
C2: Aesthetic values	Moderate	Moderate	Moderate
C3: Science and education	Good	Good	Good
C4: Cultural heritage	Moderate	Moderate	Moderate
C5: Inspiration	Good	Good	Good
C6: Natural heritage	Moderate	Moderate	Moderate

The direct evaluation process considered the initially available scores from Bryhn et al. (2015), present at three levels (0, 1 and 2) for those activities and ecosystem services that were included there. These scores were first translated into six levels, 0–5, in such a way that former 0's could become 0–1, former 1's could become 2–3 and former 2's could become 4–5. Then, scores for links between activities and ecosystem services missing in Bryhn et al. (2015) were estimated with the existing evaluations in mind. Initially, all four experts conducted separate evaluations and after this they got together to motivate the individually given scores and to compare arguments on which score would be most motivated to settle for. Within this process, the descriptions of ecosystem services and the indicators for their assessment given in Bryhn et al. (2015) played a substantial role for the argumentation about were the scores eventually ended up.

The results for the Direct/DI-method, which were assessed with respect to the entire Swedish coastline, are presented in Table 4. According to the assessment, e.g. commercial fish and shellfish harvesting and agriculture impose the generally highest influence on ecosystem services, out of the activities examined, whereas various background “activities”/processes also are important such as eutrophication and climate change. Other activities seem to have very little impact on ecosystem services in this assessment. Looking from an ecosystem service perspective, some supporting services are quite heavily affected by human activities, for instance the provisional service ‘food’ and the cultural service ‘recreation’, whereas other ecosystem services are only affected by few activities or to a restricted extent.

Table 4. *Score sheet for Direct/DI-assessment of human activities’ impact on ecosystem services. For each cell, the expert group made an assessment (0–5, where 5 is the highest) depending on the intensity/strength of the pressure and its geographical extent. More detailed arguments for the reasoning within this evaluation are provided in Bryhn et al. (2015).*

Activity	S1 BCC	S2 PP	S3 FWD	S4 BDIV	S5 HAB	S6 RSIL	R1 CA	R2 SRET	R3 EUT	R4 BIOL	R5 TOX	P1 FOOD	P2 RAW	P3 GEN	P4 CHE	P5 ORN	P6 ENRG	C1 RECR	C2 AEST	C3 SCIED	C4 CULH	C5 INSP	C6 NATH
Land claim	1	1	1	1	2	1	0	1	1	0	1	1	0	0	0	0	0	1	1	0	1	0	1
Restructuring of seabed morph	3	1	1	2	2	2	0	1	1	1	2	3	1	0	0	0	0	1	3	0	1	1	3
Extraction of minerals	1	1	1	1	1	1	0	1	1	1	1	1	2	0	0	0	0	1	2	0	1	1	2
Renewable energy generation	0	1	1	1	2	1	0	1	0	0	0	0	0	0	0	0	0	1	3	0	2	1	3
Nuclear power	1	1	1	1	1	1	0	1	0	0	1	1	1	1	0	0	0	1	1	0	1	1	2
Transmission (cables)	1	0	1	1	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	0	0	0	1
Fish and shellfish harvesting (prof.)	3	3	5	5	5	4	0	5	3	4	3	5	3	4	1	1	1	3	1	1	3	1	5
Hunting and collecting	0	0	1	3	1	1	0	0	0	0	0	1	0	0	0	0	0	3	0	0	0	1	1
Aquaculture	2	1	1	1	2	1	0	0	2	1	1	0	0	2	0	0	0	1	1	0	1	0	1
Agriculture	4	4	3	2	2	3	2	1	4	3	1	3	1	1	0	0	0	3	2	1	1	1	1
Forestry	4	4	2	2	2	2	2	1	3	2	1	2	1	0	0	0	0	2	2	1	0	1	3
Transport — infrastructure	1	1	1	2	3	1	1	1	2	2	1	2	1	0	0	0	0	2	3	0	1	1	2
Transport — shipping	1	1	1	2	2	2	1	2	2	2	2	1	1	1	0	0	0	3	3	0	2	1	2
Urban uses	1	1	1	1	3	1	1	1	2	1	1	2	1	0	0	0	0	1	2	0	2	1	2
Industrial uses	2	3	2	2	2	2	1	1	1	1	2	3	1	1	0	0	0	2	3	0	2	1	3
Waste treatment and disposal	3	4	3	2	2	2	0	1	3	3	4	4	2	1	0	0	0	3	2	0	0	1	2
Tourism and leisure infrastructure	1	1	1	1	3	1	0	2	1	1	1	2	1	0	0	0	0	1	2	0	1	1	2
Tourism and leisure activities	1	3	2	2	3	2	1	2	2	2	2	2	1	0	0	0	0	2	1	0	1	1	1
Fish and shellfish harvesting (recr.)	1	2	3	3	1	2	0	1	2	2	1	3	2	3	1	1	1	2	1	0	1	1	4
Security/defence, Military operations	0	0	0	0	1	0	0	1	0	0	1	1	0	0	0	0	0	1	1	1	1	2	1
Scientific and educational activities	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Eutrophication	5	4	4	4	5	5	2	2	5	4	1	3	2	1	0	0	0	5	3	1	1	2	4
Toxic pollution	1	0	2	2	1	2	0	0	0	2	4	5	3	1	0	0	0	3	1	0	1	2	2
Climate change CO2	4	2	2	2	2	3	3	0	1	2	1	1	1	1	0	0	0	1	1	0	0	1	1
Climate change Temperature	3	4	3	2	4	3	5	2	1	2	1	2	2	1	0	0	0	1	1	0	1	1	1
Climate change Salinity	3	2	3	5	5	3	1	2	1	2	1	2	1	2	1	1	0	1	1	0	2	1	2

The scores provide a screening and overview of the impacts of different human activities and pressures on ecosystem services. However, to use the results of the analysis to produce an aggregated result for each activity or each ecosystem service remains a challenge. One way could be to simple tally up the score for each activity as a rough indication of the negative impact on ecosystem services, with the emphasis on the word indication (Fig. 3). In reality, however, not every ecosystem service is of equal value, a fact that isn´t reflected when the total scores for each activity are tallied up. There is also a problem with double counting of certain aspects, which could be limited or possibly avoided, if the ecosystem services are separated into supportive, intermediate and final ecosystem services.

In Fig. 4, the columns of the assessments are summed up instead, thus providing an impression of the extent to which various ecosystem services are impacted by the studied human activities.

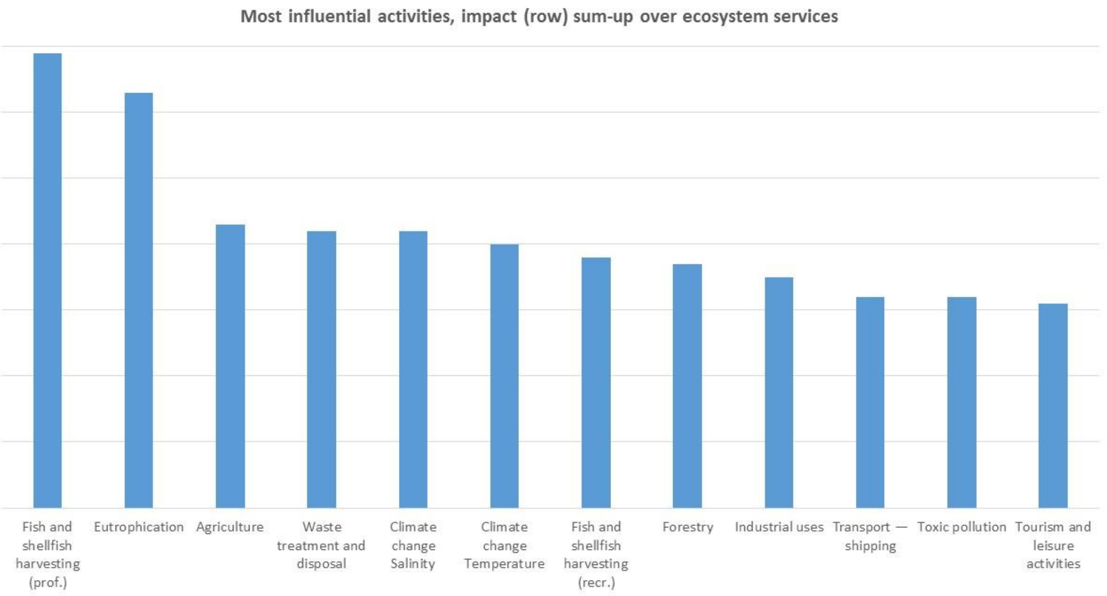

Figure 3. *Estimated impact of different human activities on ecosystem services, as a rough general estimation based on Direct/DI-evaluation (expert evaluation), presenting results for the activities which had the highest impact. Other assessed activities had relatively lower impact according to the assessment.*

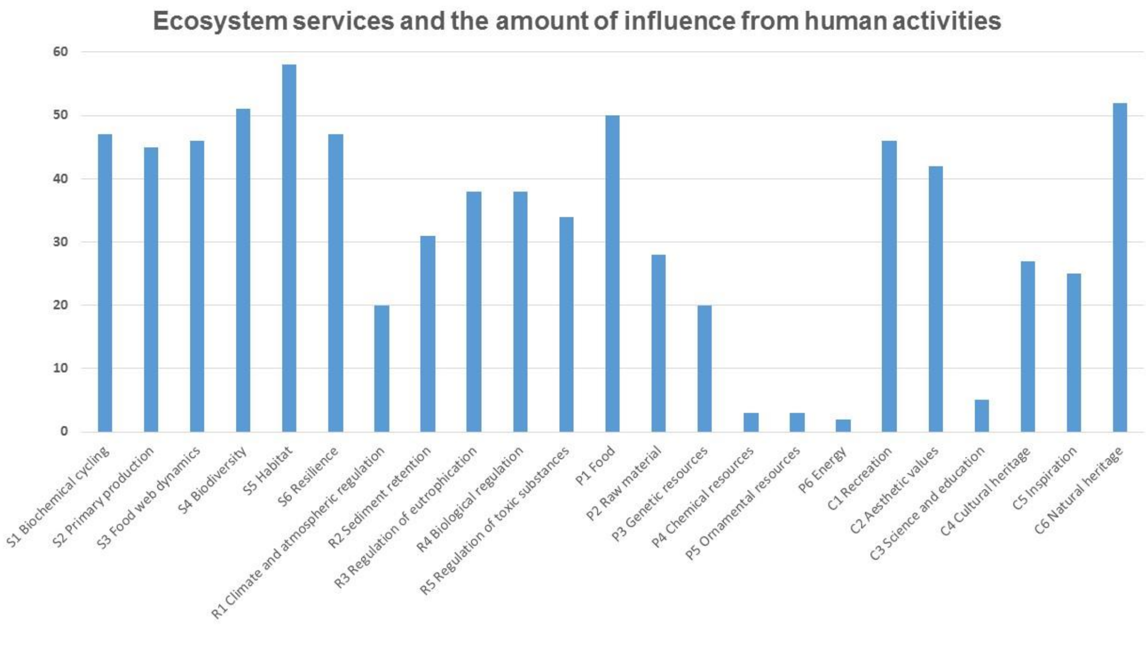

Figure 4. *Direct/DI evaluation on the summed impact of human activities on different ecosystem services, presenting a very rough impression of the extent to which these ecosystem services are estimated to be impacted by the studied human activities according to the applied expert judgement.*

The indirect/DPSI-method

The indirect (Driver-Pressure-State-Impact) method utilizes existing information on the links between pressures and ecosystem components before assessing impacts on ecosystem services. The approach is shown here with example from the spatial modelling framework Symphony[1], which is used as a maritime spatial planning tool in Sweden (see Andersen and Kallenbach 2016). The applied approach is similar to that of the Baltic Sea Impact Index (BSII), which assesses the cumulative impact of pressures from human activities in the Baltic Sea (HELCOM 2017). The assessment of impacts on ecosystem services is made by adding conversion factors for each ecosystem component, which estimate to what extent it contributes to each ecosystem service.

The impact on ecosystem services is assessed departing from the underlying "sensitivity scores" (which estimate the likely sensitivity of each ecosystem component to each pressure), or alternatively based on the "impact sums" (which estimate the likely impact from each pressure on each ecosystem component after also accounting for the spatial distribution of all pressures and ecosystem components and their overlap in the assessed area), which are both derived from Symphony (in this case). Basing the assessment on the sensitivity scores gives an assessment of the sensitivity of an ecosystem service to a certain pressure, without acknowledging the spatial extent of the pressure. Basing the assessment instead on the impact sums, gives the probably ongoing impact on that ecosystem services in the sea today, at the scale of assessment.

The indirect method also relies on expert opinions and contains more steps as compared to the direct method, but is expected to be more robust, transparent and adaptive in the longer run. In its first step, expert opinion is used to assess the sensitivity of ecosystem components to activities/pressures, but this assessment is based on evaluation by a more comprehensive set of expert opinions (within Symphony). At a second stage, the results are combined with expert evaluations of how the various ecosystem components contribute to ecosystem services. Again, this part was approached here using the same expert opinion approach as described for the Direct/DI-method by the authors of this report). Hence the first step should be less vulnerable to possible bias as compared to the second step, which was developed as part of this work. In addition, the stepwise approach could be expected to provide more refined results thanks to the finer resolution of the assessments using the intermediate stage, and be more comprehensible in a DPSI-framework setting.

It is important to note that the proposed indirect assessment is a new way of using a cumulative assessment tool, such as Symphony, and the outcomes of such an endeavour will remain unclear until further testing has been conducted. If the indirect/DPSI-method is found useful, it could also be applied to data from other cumulative impact assessment tools, such as the Baltic Sea Impact Index (see further below). With further development, it could potentially also provide a basis for evaluating outcomes of different planning scenarios with respect to ecosystem services, as well as make spatial ecosystem service analyses.

[1] Symphony is a tool that allows us to assess the cumulative environmental impact from different plan options in the marine spatial planning (SP) process. Cumulative environmental impact refers to the combined pressure from all kinds of different human activities on the marine ecosystems. The cumulative impact is eventually what determines the health of ecosystems.

When comparing the results from the Direct/DI-method and the Indirect/DPSI-method, not only the methods differ (and hence their robustness and transparency). Another evident difference is that some activities from the MSFD list (Table 1) have not been considered in Symphony and are thereby also not included in the Indirect/DPSI-method. These missing activities are:

- Fish and shellfish harvesting (recreational)
- Tourism and leisure infrastructure (including marinas)
- Nuclear power (uptake and discharge of cooling water)
- Agriculture
- Forestry
- Research, survey and educational activities
- Climate change (induced lowered salinity)

The indirect/DPSI-method: Ecosystem components versus ecosystem services – motivations for scores

This section presents the motivations for scores given as expert evaluations on the contribution of each ecosystem component to ecosystem services (Tables 5–6, Appendices 1–2) as applied in the indirect method. The assessment was made by the authors of this report. When estimating the scores, it was looked at the tables from both of two perspectives: row by row, i.e. ecosystem components (in rows) in relation to all ecosystem services (in columns), and column by column, ecosystem services (in columns) in relation to all ecosystem components (in rows).

It should be noted that for this evaluation of ecosystem components to ecosystem services, the assessment has not considered the spatial extent of the ecosystem component, but a point view has been used assuming that the ecosystem component is present. This is because the extent is already considered in the first step, which estimated the link between activity/pressures and ecosystem components.

Additionally it should be noted that for the assessment of Supporting ecosystem services, S, the scores 0–4 have been used, whereas for the direct ecosystem services R (regulating), P (provisional) and C (cultural), scores 0–2 have been used. This approach was used in order to avoid overestimation of ecosystem components that have a role in more than one group, assuming that the supporting services are the "base" and recognizing that other services are also dependent on the supporting services but that these do not have to be counted again in those groups.

A more detailed description of the scores for this expert evaluation in relation to the Symphony ecosystem components is given in Appendix 1. Corresponding numbers based on expert evaluation for the entire Baltic Sea are given in Appendix 2 in relation to the ecosystem components used in the Baltic Sea Impact Index (HELCOM 2017).

Table 5. *Scores received when estimating the contribution of different ecosystem components (Symphony list) on ecosystem services.*

Ecosystem components versus ecosystem services Symphony	S1 Biochemical cycling	S2 Primary production	S3 Food web dynamics	S4 Biodiversity	S5 Habitat	S6 Resilience	R1 Climate and atmospheric regulation	R2 Sediment retention	R3 Regulation of eutrophication	R4 Biological regulation	R5 Regulation of toxic substances	P1 Food	P2 Raw material	P3 Genetic resources	P4 Chemical resources	P5 Ornamental resources	P6 Energy	C1 Recreation	C2 Aesthetic values	C3 Science and education	C4 Cultural heritage	C5 Inspiration	C6 Natural heritage
Angiosperms	3	4	4	4	4	4	2	2	2	1	1	0	1	2	0	0	1	2	2	1	1	1	1
Artificial Reefs Total	3	2	3	4	4	0	1	1	1	1	1	0	0	1	0	1	1	2	1	1	1	1	0
Birds Coastal	1	0	3	4	4	2	0	0	0	0	0	0	0	2	0	1	0	2	2	2	2	2	1
Cod	1	0	4	2	0	4	0	0	2	2	2	2	0	1	1	0	1	2	1	2	2	2	1
Deep Reef	3	0	3	4	4	3	0	1	1	1	1	1	0	2	1	1	0	0	2	1	0	1	1
Eel Migration	1	0	1	2	0	2	0	0	0	0	1	1	0	1	0	0	0	1	1	2	2	1	1
Grey Seals	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Haploops Reef	3	0	3	4	4	3	0	2	1	1	1	1	0	2	0	1	0	0	0	1	0	1	1
Harbour Seals	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Hardbottom Aphotic	3	0	3	2	2	2	0	0	1	0	0	1	1	2	0	0	0	0	0	1	0	0	0
Hardbottom Deep	3	0	3	2	2	2	0	0	1	0	0	1	1	2	0	0	0	0	0	1	0	0	0
Hardbottom Photic	4	4	4	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
Herring	1	0	3	2	0	2	0	0	2	1	2	2	2	1	1	0	1	2	1	1	2	1	1
Mussel Reefs Total	3	0	3	4	4	4	1	2	2	2	2	2	1	2	1	1	1	2	2	1	1	1	1
Plankton Community	4	4	4	4	1	3	2	0	2	1	1	1	1	2	1	0	1	0	0	1	1	1	1
Porpoise Baltic	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Porpoise Baltic Reproduction	1	0	2	1	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	1	1
Porpoise Belt Reproduction	1	0	2	1	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	1	1
Porpoise Beltsea	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Porpoise North Reproduction	1	0	2	1	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	1	1
Porpoise Northsea	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Ringed Seals	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
Rivermouth Fish	1	0	4	4	4	2	0	0	1	2	1	2	0	1	0	0	0	2	2	2	2	2	1
Seabird Winter Coastal	1	0	3	3	4	2	0	0	0	0	0	0	0	2	0	1	0	2	2	2	2	2	1
Seabird Winter Offshore	1	0	3	3	4	2	0	0	0	0	0	0	0	2	0	0	0	2	2	2	1	2	1
Softbottom Aphotic	3	0	3	2	2	2	1	2	2	1	2	1	1	2	0	0	0	0	0	1	0	0	0
Softbottom Deep	3	0	3	2	2	2	1	2	2	1	2	1	1	2	0	0	0	0	0	1	0	0	0
Softbottom Photic	4	4	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
Spawning Cod	1	0	4	2	4	4	0	0	1	1	2	2	0	1	0	0	1	2	1	2	1	1	1
Spawning Fish	1	0	3	1	4	3	0	0	1	2	1	2	0	1	0	0	0	2	1	1	1	1	1
Sprat	1	0	3	1	0	2	0	0	2	0	2	2	2	1	1	0	1	1	1	1	1	1	1
Transportbottom Aphotic	3	0	3	2	2	2	0	0	1	0	0	1	1	2	0	0	0	0	0	1	0	0	0
Transportbottom Deep	3	0	3	2	2	2	0	0	1	0	0	1	1	2	0	0	0	0	0	1	0	0	0
Transportbottom Photic	4	3	3	4	4	4	2	1	1	1	1	1	1	2	0	1	0	1	1	1	1	1	1
Vendace	1	0	3	2	0	2	0	0	2	0	2	2	0	1	0	0	1	2	1	1	2	1	1

Table 6. *Scores received when estimating the contribution of different ecosystem components (Baltic Sea Impact Index list, HELCOM 2017) on ecosystem services.*

ECOSYSTEM COMP VERSUS ECOSYSTEM SERVICES (BALTIC SEA IMPACT INDEX)	S1 Biochemical cycling	S2 Primary production	S3 Food web dynamics	S4 Biodiversity	S5 Habitat	S6 Resilience	R1 Climate/atmosph reg	R2 Sediment retention	R3 Reg of eutrophication	R4 Biological regulation	R5 Reg of toxic substances	P1 Food	P2 Raw material	P3 Genetic resources	P4 Chemical resources	P5 Ornamental resources	P6 Energy	C1 Recreation	C2 Aesthetic values	C3 Science and education	C4 Cultural heritage	C5 Inspiration	C6 Natural heritage
01. Productive surface waters	4	4	4	4	1	3	2	0	2	1	1	1	1	2	1	0	1	0	0	1	1	1	1
02. Oxygenated deep waters	3	0	3	3	2	2	1	2	2	1	2	1	1	2	0	0	0	0	0	1	0	1	0
03. Infralittoral hard bottom	4	4	4	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
04. Infralittoral sand	4	4	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
05. Infralittoral mud	4	4	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
06. Infralittoral mixed	4	4	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
07. Circalittoral hard bottom	4	3	4	4	4	3	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
08. Circalittoral sand	4	3	4	4	4	3	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
09. Circalittoral mud	4	3	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
10. Circalittoral mixed	4	3	4	4	4	4	2	2	2	1	2	1	1	2	1	1	1	1	1	1	1	1	1
11. Furcellaria lumbricalis	4	4	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	1	1	1	1	1	1
12. Zostera marina	4	4	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
13. Charophytes	4	4	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
14. Mytilus edulis	3	0	3	4	4	4	1	2	2	2	2	2	1	2	1	1	1	2	2	1	1	1	1
15. Fucus sp.	4	4	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	1	1	1	1
16. Sandbanks which are slightly covered by sea water at all time (1110)	3	3	3	4	4	3	2	2	2	1	1	1	1	2	1	1	1	1	1	2	1	1	1
17. Estuaries (1130)	3	3	3	4	4	4	2	2	2	2	2	1	1	2	1	1	1	2	2	2	1	1	2
18. Mudflats and sandflats not covered by seawater at low tide (1140)	3	3	3	4	4	3	2	2	2	1	1	1	1	2	1	1	1	1	1	2	1	1	1
19. Coastal lagoons (1150)	3	3	3	4	4	4	2	2	2	2	2	1	1	2	1	1	1	2	2	2	1	1	2
20. Large shallow inlets and bays (1160)	3	3	3	4	4	4	2	2	2	2	2	1	1	2	1	1	1	2	2	2	1	1	2
21. Reefs (1170)	3	3	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	2	1	1	1
21. Submarine structures made by leaking gas (1180)	3	3	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	1	1	2	1	1	1
22. Baltic Esker Islands (UW parts, 1610)	3	3	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	2	1	1	2
24. Boreal Baltic islets and small islands (UW parts, 1620)	3	3	3	4	4	4	2	2	2	1	1	1	1	2	1	1	1	2	2	2	1	1	2
25. Cod abundance	1	0	4	2	0	4	0	0	2	2	2	2	0	1	1	0	1	2	1	2	2	2	1
26. Cod spawning area	1	0	3	2	4	4	0	0	1	1	2	2	0	1	0	0	1	2	1	2	1	1	1
27. Herring abundance	1	0	3	2	0	2	0	0	2	1	2	2	2	1	1	0	1	2	1	1	2	1	1
28. Sprat abundance	1	0	3	1	0	2	0	0	2	0	2	2	2	1	1	0	1	1	1	1	1	1	1
29. Distribution of demersal spawning flounder	1	0	3	1	4	3	0	0	1	1	1	2	0	1	0	0	0	2	1	1	2	1	1
30. Abundance of pelagic spawning flounder	1	0	3	1	4	3	0	0	1	1	1	2	0	1	0	0	0	2	1	1	2	1	1
31. Recruitment areas of perch	1	0	3	1	4	3	0	0	2	2	2	2	0	1	0	0	0	2	1	1	2	1	1
32. Recruitment areas of pikeperch	1	0	3	1	4	3	0	0	2	2	2	2	0	1	0	0	0	2	1	1	2	1	1
33. Recruitment areas of roach	1	0	3	1	4	3	0	0	1	1	1	1	0	1	0	0	0	0	1	1	2	1	1
34. Wintering seabirds	1	0	3	3	4	2	0	0	0	0	0	0	0	2	0	1	0	2	2	2	1	2	1
35. Breeding seabird colonies	1	0	3	4	4	2	0	0	0	0	0	0	0	2	0	1	0	2	2	2	2	2	1
36. Migration routes for birds	0	0	3	3	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
37. Grey seal abundance	1	0	3	2	0	2	0	0	0	1	0	0	0	1	0	0	0	2	2	2	1	2	1
38. Grey seal haulouts	1	0	2	2	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
39. Harbour seal abundance	1	0	3	2	0	2	0	0	0	1	0	0	0	1	0	0	0	2	2	2	1	2	1
40. Harbour seal haulouts	1	0	2	2	4	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1
41. Ringed seal distribution	1	0	3	2	0	2	0	0	0	1	0	0	0	1	0	0	0	2	2	2	1	2	1
42. Distribution of harbour porpoise	1	0	3	2	0	2	0	0	0	0	0	0	0	1	0	0	0	2	2	2	1	2	1

First results from the indirect/DPSI-method based on Symphony **sensitivity scores**

The assessment where links between activities/pressures and ecosystem components are quantified by **sensitivity scores** emphasizes the influence from intense pressures (even in cases where they do not have a broad geographical extent). The results thus indicate highest sensitivity from commercial fishing (catch), activities causing habitats loss and disturbance (such as dredging, dumping and shipping) but also background levels of nutrients, toxic compounds and climate change (Table 7). Considering ecosystem services, the highest scores are obtained for supporting services in general, genetic resources and many cultural ecosystem services (Table 7).

Table 7. *First results based on the indirect/DPSI-method using sensitivity scores to evaluate the impact of activities/pressures on ecosystem services.*

Second run: This uses the raw "own expert" scores from our table of ecosystem components versus ecosystem services	S1 Biochemical cycling	S2 Primary production	S3 Food web dynamics	S4 Biodiversity	S5 Habitat	S6 Resilience	R1 Climate and atmospheric regulation	R2 Sediment retention	R3 Regulation of eutrophication	R4 Biological regulation	R5 Regulation of toxic substances	P1 Food	P2 Raw material	P3 Genetic resources	P4 Chemical resources	P5 Ornamental resources	P6 Energy	C1 Recreation	C2 Aesthetic values	C3 Science and education	C4 Cultural heritage	C5 Inspiration	C6 Natural heritage
Birdhunt	0,6	0	1,8	2	0,6	1,2	0	0	0	0	0	0	0	1,2	0	0,4	0	1,2	1,2	1,2	1	1,2	0,6
Catch Gillnet	23	3,4	51	38	17	40	2,4	3,6	12	8,6	12	13	4,8	22	2,7	3	4,7	30	26	29	20	24	16
Catch Pelagic trawl	7,4	0	23	13	3,6	18	0	0	7,6	5	8,6	10	3,2	7,4	1,8	0	3,6	14	10	11	9,6	9,2	7,4
Catch Bottom trawl	30	8,8	42	29	22	36	6,4	7,2	17	9,2	14	16	8	20	3	2,4	4,8	15	11	17	10	10	8,4
Turbidity Bottom trawl	26	12	33	29	23	28	7,2	8,2	14	9	11	11	6,2	16	3,4	3,4	4,6	10	9,4	12	8	9	7,4
Turbidity Dredging	26	12	33	29	23	28	7,2	8,2	14	9	11	11	6,2	16	3,4	3,4	4,6	10	9,4	12	8	9	7,4
Turbidity Shipping	26	12	33	29	23	28	7,2	8,2	14	9	11	11	6,2	16	3,4	3,4	4,6	10	9,4	12	8	9	7,4
Turbidity Mining	26	12	33	29	23	28	7,2	8,2	14	9	11	11	6,2	16	3,4	3,4	4,6	10	9,4	12	8	9	7,4
Abrasion Bottomtrawl	34	10	40	34	31	35	7,6	12	16	9	11	12	8,2	22	3,4	4,2	3,8	9,8	11	15	6,4	9,2	7,8
Habitatloss Dumping	40	14	48	43	38	40	9,6	15	20	13	17	16	9,2	25	4,6	6,2	6,4	14	13	17	10	12	9,4
Habitatloss Fishfarm	26	9,2	30	28	25	25	7	11	13	8,2	11	9,4	6,6	17	2,8	4,2	3,4	6,8	7,4	10	5,6	6,6	5,4
Habitatloss Musselfarming	26	9,2	30	28	25	25	7	11	13	8,2	11	9,4	6,6	17	2,8	4,2	3,4	6,8	7,4	10	5,6	6,6	5,4
Abrasion Dredging	44	16	50	46	42	43	11	16	22	14	17	17	11	27	4,6	6,6	6,6	13	12	17	9,6	11	9,2
Habitatloss Coastal Exploitation	19	13	26	23	18	24	7,4	6,6	11	8	9	8,4	5	12	2,8	3,2	4,4	10	8,2	9	8,2	7,8	6,4
Infrastructure	11	4,6	13	11	11	12	3	4,2	5,4	3,5	4,3	4	2,6	7	1	1,4	1,5	2,6	3	4,1	2	2,6	2,6
Habitat Loss Mining	26	9	33	33	28	29	6	8,6	11	8,8	9,4	9,6	5	18	2,2	5,2	4	11	12	13	7,9	10	7,9
Noise 125Hz Shipping	11	2,6	19	15	8	14	1,8	2	5	2,8	4,4	4,8	2,6	9,3	1	1,6	1,6	9,4	8,2	9,8	6,9	7,6	4,9
Noise 125Hz Wavepower	11	2,6	19	15	8	14	1,8	2	5	2,8	4,4	4,8	2,6	9,3	1	1,6	1,6	9,4	8,2	9,8	6,9	7,6	4,9
Noise 125Hz Windpower	11	2,6	19	15	8	14	1,8	2	5	2,8	4,4	4,8	2,6	9,3	1	1,6	1,6	9,4	8,2	9,8	6,9	7,6	4,9
Noise 2000Hz Shipping	4,8	0	13	9,7	2,6	9,9	0	0	1	0,5	1,1	1,2	0,8	6	0,4	0,8	0,5	9,4	9	9,1	5,8	7,8	4,8
Boating Noise	4,8	0	13	9,7	2,6	9,9	0	0	1	0,5	1,1	1,2	0,8	6	0,4	0,8	0,5	9,4	9	9,1	5,8	7,8	4,8
Explosion PM	23	9,6	22	19	19	18	6,4	6,8	9,6	4	5,8	6,2	6,4	13	1,4	2,6	2	4	3,6	6,8	2,8	2,8	2,4
Explosion SPL	15	0	43	28	5,8	35	0	0	10	6,6	12	13	4	16	3	0,4	4,8	29	24	27	20	22	15
Oilspill 2knots Shipping	15	6	31	26	10	24	3,2	2	6,8	4,4	6,6	7	3,2	15	2	3	3	18	16	17	14	15	10
Oilspill 2knots Wrecktif	23	8	35	31	21	30	5	6,4	11	8,6	10	11	4,2	17	3	4,2	4,2	15	14	16	11	13	9,4
Tox Metal Background	17	5,2	28	22	14	23	3,9	5,1	8,7	6	8,1	7,4	3,7	13	1,7	2	2,7	12	11	13	8,5	10	7,4
Tox Metal Fiberbanks	17	5,2	28	22	14	23	3,9	5,1	8,7	6	8,1	7,4	3,7	13	1,7	2	2,7	12	11	13	8,5	10	7,4
Tox Metal Mercurydump	17	5,2	28	22	14	23	3,9	5,1	8,7	6	8,1	7,4	3,7	13	1,7	2	2,7	12	11	13	8,5	10	7,4
Tox Metal Military	17	5,2	28	22	14	23	3,9	5,1	8,7	6	8,1	7,4	3,7	13	1,7	2	2,7	12	11	13	8,5	10	7,4
Tox Mine Risk	17	5,2	28	22	14	23	3,9	5,1	8,7	6	8,1	7,4	3,7	13	1,7	2	2,7	12	11	13	8,5	10	7,4
Tox Munition	23	6,4	39	30	18	31	4,4	5,6	13	7,8	12	13	6,6	18	3	2,6	4,6	17	14	17	13	14	9,7
Tox Synthetic Background	19	6,2	32	25	15	26	4,4	5,4	8,7	5,4	8	6,7	3,9	15	2	2,3	2,9	15	14	16	9,8	13	8,9
Tox Synthetic Harbor	19	6,2	32	25	15	26	4,4	5,4	8,7	5,4	8	6,7	3,9	15	2	2,3	2,9	15	14	16	9,8	13	8,9
Tox Synthetic Industry	29	8,9	43	34	22	35	6	6,8	13	7	10	10	6,7	21	2,9	3,4	4,1	19	17	21	13	16	11
Tox Synthetic Treatmentplants	29	8,9	43	34	22	35	6	6,8	13	7	10	10	6,7	21	2,9	3,4	4,1	19	17	21	13	16	11
Boating Pollution	29	8,9	43	34	22	35	6	6,8	13	7	10	10	6,7	21	2,9	3,4	4,1	19	17	21	13	16	11
Nitrogen Background	24	11	32	27	21	28	7,2	8,2	12	7,6	9,6	8,6	5,8	17	2,6	3	3,8	11	10	13	7,7	9,2	7,3
Nitrogen Fishfarming	24	11	32	27	21	28	7,2	8,2	12	7,6	9,6	8,6	5,8	17	2,6	3	3,8	11	10	13	7,7	9,2	7,3
Phosphorous Background	8,7	3	15	12	8	14	2	2,6	3,8	3,4	4	3,8	1,2	7,1	0,8	1,4	1,2	7,6	7,2	7,6	4,5	6	4,5
Anoxia Background	42	13	55	48	39	47	9,2	13	20	13	17	17	9,4	29	4,2	6,8	6,2	19	17	22	14	15	12
Pathogens Fish farm	1,7	0,4	5,1	4	1,1	3,5	0,2	0	1,2	1,9	1,3	2,1	0,1	1,5	0,1	0	0,3	2,6	2,2	2,5	2	2,3	1,4
Pathogens Treatmentplants	3,5	0,8	7,1	4,8	1,8	5,8	0,5	0,2	0,6	0,4	0,4	0,4	0,3	3	0,3	0,1	0,3	4,9	5	5,1	2,7	3,9	2,7
EMF	0,8	0	2,4	1,8	0,6	2,2	0	0	0,6	1	1	1,4	0	0,8	0	0	0,2	1,4	1	1,4	1,2	1	0,8
TempIncrease Summer 2050	24	6,8	33	27	19	27	5,2	7	14	7,6	11	12	6,6	17	3,4	3	4	10	9,4	12	8,3	9,2	7,3
TempIncrease Winter 2050	24	6,8	33	27	19	27	5,2	7	14	7,6	11	12	6,6	17	3,4	3	4	10	9,4	12	8,3	9,2	7,3
OA 2050	25	7,2	34	28	22	28	5	7,2	13	8,2	11	12	6,1	17	3,5	3,6	4,2	11	11	13	8,4	9,7	7,8
Avoidance Windpower	1,8	0	5,4	6	1,8	3,6	0	0	0	0	0	0	0	3,6	0	1,2	0	3,6	3,6	3,6	3	3,6	1,8
Microplastics	21	7	31	24	16	25	4,7	5,1	11	5,9	9,1	9,6	6	15	2,8	2,3	3,7	11	9,9	13	8,5	9,5	7,2
Macroplastics	8,7	4	16	14	6,8	12	2,2	2	2,5	1,7	1,9	1,4	1,1	7,6	0,9	1,8	1,1	8,7	8,8	8,8	5,8	8,2	5
Ghostnet	33	7,8	55	42	25	44	5,6	7	14	9	11	13	6,6	26	2,8	3,8	3,8	26	24	29	17	21	14

First results from the indirect/DPSI-method based on Symphony **impact sums**

The indirect/DPSI evaluation of impacts from activities/pressures on ecosystem services based on **impact sums** emphasizes activities which are present over larger areas as it also takes the geographical extent into account (while the sensitivity of the ecosystem component to the pressure maybe gets relatively lower influence in comparison to when sensitivity scores are used). Based on these results, the highest impact is seen from shipping (noise, oil spills) and from environmental background pressures such as anoxia, nutrients, toxic compounds and climate change (Table 8). However, with regard to the high scores for shipping, this may be an exaggeration and due to relatively large areas considered as affected by this activity and especially noise from shipping is probably not as disastrous for many ecosystem components and thereby ecosystem services as this table suggests. Similarly, this method seems to miss the effects of small boats, whose effects are widely distributed and can be at least as damaging to the environment as effects from larger ships. From before, we also mentioned above a number of activities that are missing from Symphony in comparison with MSFD and thereby also from the Indirect/DPSI-evaluation conducted for this report. Considering results for ecosystem services, similar as to the results based on sensitivity scores, the supporting services in general, genetic resources and many cultural ecosystem services seem to score high.

In Fig. 5, the scores of each activity are tallied up as indications of their estimated summed negative impact on ecosystem services. In Fig. 6, the assessment results are summed up with respect to each ecosystem services, thus providing an impression of to what extent various ecosystem services are impacted by the studied human activities. For both these measures, please consider the same precautionary warnings as were present for Figs 3–4 above when tallying up the results.

The results presented here are based on interim assessment results from Symphony regarding impact sums, and should be viewed upon as a demonstration of the method rather than as a final impact assessment. For a more accurate estimation, the assessments should be done separately for the Gulf of Bothnia, the Baltic Proper and for Kattegat/Skagerrak, since the relative importance of human activities could be different in these basins, as well as the distribution of ecosystem components.

Indirect/DPSI-method based on Baltic Sea Impact Index

In order to assess the possibilities to do similar analyses at the scale of the entire Baltic Sea, the evaluation was also made in relation to the ecosystem components used in Baltic Sea Impact Index, in addition to the list from Symphony presented above. A table proposing conversion factors for estimating the contribution of ecosystem components to ecosystem services based on the Baltic Sea Impact Index list of Ecosystem components is presented in Table 6 and the motivations for the respective scores are given in Appendix 2.

Table 8. *First results based on the indirect/DPSI-method using impact sums to evaluate the impact of activities/pressures on ecosystem services.*

Fifth run: This uses impact sums and the raw "own expert" scores from our table of ecosystem components versus ecosystem services, compare with run 2 which uses impscores	S1 Biochemical cycling	S2 Primary production	S3 Food web dynamics	S4 Biodiversity	S5 Habitat	S6 Resilience	R1 Climate and atmospheric regulation	R2 Sediment retention	R3 Regulation of eutrophication	R4 Biological regulation	R5 Regulation of toxic substances	P1 Food	P2 Raw material	P3 Genetic resources	P4 Chemical resources	P5 Ornamental resources	P6 Energy	C1 Recreation	C2 Aesthetic values	C3 Science and education	C4 Cultural heritage	C5 Inspiration	C6 Natural heritage
Abrasion Bottomtrawl	0,6	0,0	1,0	0,6	0,4	0,8	0,1	0,2	0,3	0,2	0,3	0,3	0,2	0,5	0,0	0,0	0,1	0,4	0,3	0,5	0,2	0,3	0,2
Abrasion Dredging	1,1	0,1	1,2	1,5	1,5	1,1	0,1	0,7	0,4	0,4	0,4	0,4	0,0	0,7	0,1	0,4	0,0	0,1	0,2	0,4	0,1	0,4	0,4
Anoxia Background	10,9	3,0	13,8	12,3	9,9	11,1	2,2	3,1	5,0	3,1	4,1	4,3	2,6	7,5	1,1	1,7	1,6	4,7	4,2	5,8	3,6	3,9	2,7
Avoidance Windpower	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Birdhunt	0,1	0,0	0,4	0,4	0,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,1	0,0	0,2	0,2	0,2	0,2	0,2	0,1
Boating Noise	0,1	0,0	0,3	0,2	0,1	0,2	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,2	0,2	0,2	0,1	0,2	0,1
Boating Pollution	0,5	0,2	0,8	0,7	0,5	0,7	0,1	0,2	0,2	0,1	0,2	0,1	0,1	0,4	0,1	0,1	0,1	0,4	0,4	0,4	0,3	0,4	0,2
Catch Bottom trawl	0,6	0,0	1,2	0,6	0,3	1,0	0,1	0,1	0,4	0,3	0,4	0,4	0,1	0,5	0,1	0,0	0,2	0,5	0,4	0,6	0,4	0,4	0,3
Catch Gillnet	1,0	0,1	2,0	1,7	0,9	1,6	0,0	0,3	0,4	0,4	0,4	0,4	0,1	0,9	0,1	0,2	0,1	1,0	1,0	1,1	0,7	1,0	0,6
Catch Pelagic trawl	0,1	0,0	0,2	0,1	0,0	0,2	0,0	0,0	0,1	0,0	0,1	0,1	0,1	0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1
EMF	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Explosion PM	1,0	0,3	0,9	0,7	0,7	0,7	0,2	0,2	0,4	0,1	0,2	0,3	0,3	0,6	0,0	0,1	0,1	0,1	0,1	0,3	0,1	0,1	0,1
Explosion SPL	0,1	0,0	0,2	0,1	0,0	0,2	0,0	0,0	0,0	0,0	0,1	0,1	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1
Habitat Loss Mining	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Habitatloss Coastal Exploitation	0,7	0,6	1,1	1,1	0,7	0,9	0,3	0,3	0,4	0,4	0,3	0,4	0,1	0,5	0,1	0,1	0,1	0,5	0,5	0,4	0,4	0,4	0,3
Habitatloss Dumping	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Habitatloss Fishfarm	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Habitatloss Musselfarming	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Infrastructure	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Nitrogen Background	7,2	2,9	9,8	8,5	6,3	8,3	1,9	2,1	3,3	2,1	2,4	2,4	1,7	5,0	0,8	0,9	1,1	3,6	3,6	4,1	2,5	3,2	2,3
Nitrogen Fishfarming	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Noise 125Hz Shipping	3,2	0,7	5,9	5,2	2,1	4,6	0,5	0,5	1,2	0,8	1,3	1,5	0,7	2,9	0,3	0,5	0,4	3,3	3,0	3,6	2,7	2,9	1,8
Noise 125Hz Wavepower	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Noise 125Hz Windpower	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Noise 2000Hz Shipping	0,2	0,0	0,4	0,3	0,1	0,3	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,2	0,0	0,0	0,0	0,3	0,3	0,3	0,2	0,3	0,2
OA 2050	9,7	3,3	13,3	11,4	8,4	10,6	2,2	2,7	5,2	3,4	4,2	4,5	2,7	6,5	1,5	1,4	1,8	4,6	4,3	5,3	3,6	4,0	3,0
Oilspill 2knots Shipping	4,0	1,4	8,3	7,3	2,2	6,8	0,7	0,4	1,6	1,1	1,8	1,9	0,9	4,0	0,6	0,6	0,7	4,9	4,6	5,2	4,1	4,5	2,9
Oilspill 2knots Wreck	0,1	0,0	0,1	0,2	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1
Phosphorous Background	6,0	2,4	8,3	6,9	4,9	7,0	1,5	1,5	2,6	1,5	1,8	1,9	1,5	4,3	0,6	0,7	0,7	3,0	3,0	3,6	2,1	2,6	2,0
TempIncrease Winter 2050	8,8	2,9	11,8	10,2	7,2	9,8	2,1	2,5	5,0	3,1	4,0	4,4	2,8	6,2	1,6	1,2	1,5	3,3	3,4	4,3	3,0	3,3	2,6
Tox Metal Background	2,4	0,8	3,8	3,0	1,7	2,9	0,6	0,6	1,4	0,9	1,2	1,1	0,7	1,8	0,3	0,2	0,4	1,5	1,3	1,7	1,2	1,3	0,9
Tox Metal Fiberbanks	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Tox Metal Mercurydump	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Tox Metal Military	0,3	0,1	0,5	0,4	0,2	0,4	0,1	0,1	0,2	0,1	0,1	0,1	0,1	0,2	0,0	0,0	0,1	0,2	0,2	0,2	0,2	0,2	0,1
Tox Mine Risk	0,4	0,1	0,6	0,5	0,2	0,5	0,1	0,1	0,2	0,1	0,1	0,1	0,1	0,3	0,0	0,0	0,1	0,3	0,3	0,3	0,2	0,3	0,2
Tox Munition	0,3	0,0	0,6	0,4	0,2	0,5	0,0	0,0	0,2	0,1	0,3	0,3	0,1	0,2	0,1	0,0	0,1	0,3	0,2	0,3	0,2	0,2	0,2
Tox Synthetic Background	4,5	1,5	7,4	5,8	3,1	5,7	1,0	1,1	1,9	1,2	1,7	1,4	1,0	3,4	0,5	0,5	0,7	3,4	3,2	3,8	2,3	3,1	2,0
Tox Synthetic Harbor	0,5	0,3	0,7	0,7	0,5	0,6	0,2	0,2	0,2	0,1	0,2	0,1	0,1	0,4	0,1	0,1	0,1	0,3	0,3	0,3	0,2	0,3	0,2
Tox Synthetic Industry	0,0	0,0	0,1	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Tox Synthetic Treatmentplants	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Turbidity Bottom trawl	0,4	0,1	0,6	0,5	0,2	0,6	0,1	0,1	0,2	0,2	0,3	0,3	0,1	0,3	0,1	0,0	0,1	0,2	0,1	0,3	0,2	0,2	0,1
Turbidity Dredging	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Turbidity Mining	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
Turbidity Shipping	0,2	0,1	0,2	0,2	0,2	0,2	0,0	0,1	0,1	0,1	0,1	0,1	0,0	0,1	0,0	0,0	0,0	0,1	0,1	0,1	0,1	0,1	0,1

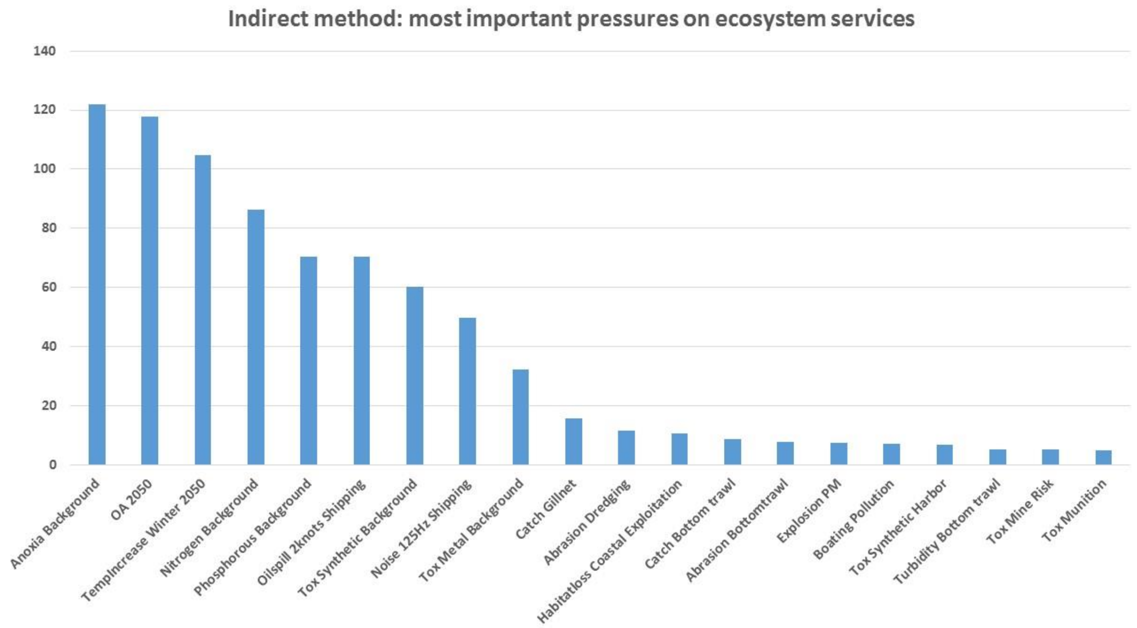

Figure 5. *Estimated impact of different human activities on ecosystem services using Indirect/DPSI-evaluation and impact sums (information of geographical extent included presenting the activities or background factors which had the highest sums to the left.*

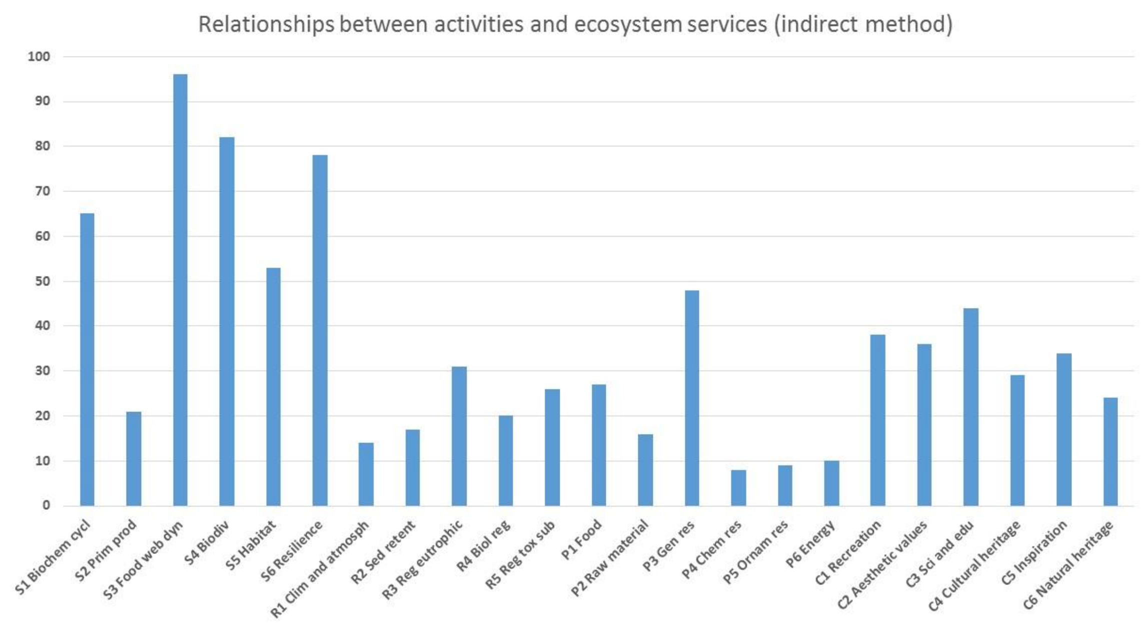

Figure 6. *Indirect/DPSI-evaluation on the summed impact of human activities on different ecosystem services, presenting the extent to which these ecosystem services are estimated to be impacted by the studied human activities.*

The dependency of human activities on ecosystem services

For further analyses of relationships between human activities and ecosystem services, we also investigated dependencies from the other way round, i.e. asked the question: "what is the dependency of various human activities on the marine ecosystem services"? This has tentatively been done before for Swedish conditions by HaV (2012), but assessing fewer activities and using only the scores 0 and 1. Within the current work, the activities listed in Annex III in the Marine Strategy Framework Directive and deemed relevant for the Baltic Sea region were given scores based on their evaluated dependency on each ecosystem service at a scale within a range of 0–4, where 4 is the highest degree of dependence. The score was set for each activity - ecosystem service combination, assessing the same ecosystem services as presented above and in alignment with Bryhn et al. (2015). The assessment was made by expert judgement by the authors of this report, using the same procedure as in the assessments of impacts on ecosystem services as described above. Thus, it was looked at the table from both of two perspectives: row by row, i.e. human activities (in rows) in relation to ecosystem services (in columns), and column by column, ecosystem services (in columns) in relation to human activities (in rows). However, the focus of the assessment was on "ecosystem capital", not abiotic services and flows. In the evaluation, the recommendations by Ivarsson et al. (2017) were also considered. The suggested steps by these authors are presented in Fig. 7, and include separate evaluations of the dependency of the quantity and the dependency of the quality of the ecosystem service in question. Subsequently, these are weighed together to the assigned scores.

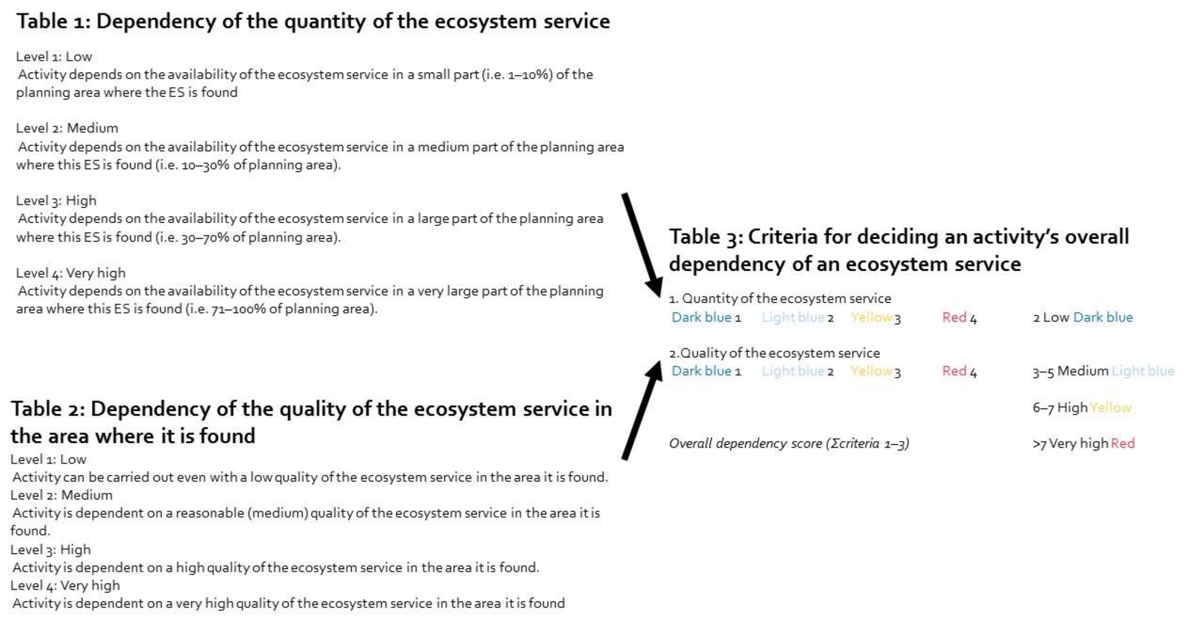

__Figure 7.__ The suggested assessment steps by Ivarsson et al. (2017) for evaluation of the dependency of human activities on ecosystem services.

The resulting scores to assess the dependency of various human activities on ecosystem services can be seen in Table 9. Commercial and recreational fisheries as well as hunting and collecting of species are very dependent on certain supporting, regulating and provisioning marine ecosystem services, according to this assessment, whereas various tourism-related activities are very dependent on cultural marine ecosystem services (Fig. 8). Other activities such as shipping, agriculture, forestry, transmission (cables), in turn, have very low dependency on marine ecosystem services, i.e. they can be expected to take place regardless of the quantity and quality of the ecosystem services (Fig. 8). Looking from the perspective of ecosystem services, it can also be seen that the quantity and quality of some marine ecosystem services are potentially significant for many human activities, whereas other ecosystem services are so for only a few activities (Fig. 9). For both these exercises, in Figs 8–9, i.e. summing up rows and columns, please consider the same precautionary warnings as were present for Figs 3–4 and Figs 5–6 above when tallying up the scores.

Table 9. *Estimated dependency of human activities on ecosystem services, according to expert judgement, considering suggested assessment steps by Ivarsson et al. (2017).*

Activity	S1 BCC	S2 PP	S3 FWD	S4 BDIV	S5 HAB	S6 RSIL	R1 CA	R2 SRET	R3 EUT	R4 BIOL	R5 TOX	P1 FOOD	P2 RAW	P3 GEN	P4 CHE	P5 ORN	P6 ENRG	C1 RECR	C2 AEST	C3 SCIED	C4 CULH	C5 INSP	C6 NATH
Land claim	1	1	0	0	0	0	1	4	0	0	0	0	1	0	1	0	0	1	0	1	0	0	0
Restructuring of seabed morph	1	1	0	0	0	0	0	4	1	0	2	0	0	0	0	0	0	1	0	1	0	0	0
Extraction of minerals	1	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Renewable energy generation	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Nuclear power	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0
Transmission (cables)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0
Fish and shellfish harvesting (prof.)	1	3	4	4	4	2	1	1	4	4	2	4	2	1	1	0	1	0	0	2	1	1	1
Hunting and collecting	1	2	3	2	3	2	1	0	2	2	1	4	1	0	0	1	0	2	0	1	1	1	1
Aquaculture	1	0	1	1	1	1	0	0	1	1	2	2	1	1	0	0	0	0	0	2	1	0	0
Agriculture	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Forestry	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Transport — infrastructure	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	0	0	1	0	0
Transport — shipping	1	0	0	0	0	0	1	1	0	0	0	1	0	0	0	0	0	1	1	0	1	0	0
Urban uses	1	0	0	0	0	0	2	0	1	1	1	1	0	0	0	0	1	1	1	1	2	0	1
Industrial uses	1	0	0	0	0	0	1	0	0	0	0	0	1	0	1	0	1	0	0	1	0	0	0
Waste treatment and disposal	1	0	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	1	0	0	0
Tourism and leisure infrastructure	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	0	4	4	1	4	4	4
Tourism and leisure activities	1	2	1	2	2	1	1	0	2	0	1	1	0	0	0	1	0	4	4	0	4	4	4
Fish and shellfish harvesting (recr.)	1	3	3	4	3	2	1	0	1	1	1	2	0	0	0	1	0	4	2	1	2	4	4
Security/defence, Military operations	1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	1	0	0	1	1	0	0
Scientific and educational activities	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	4	1	2	1

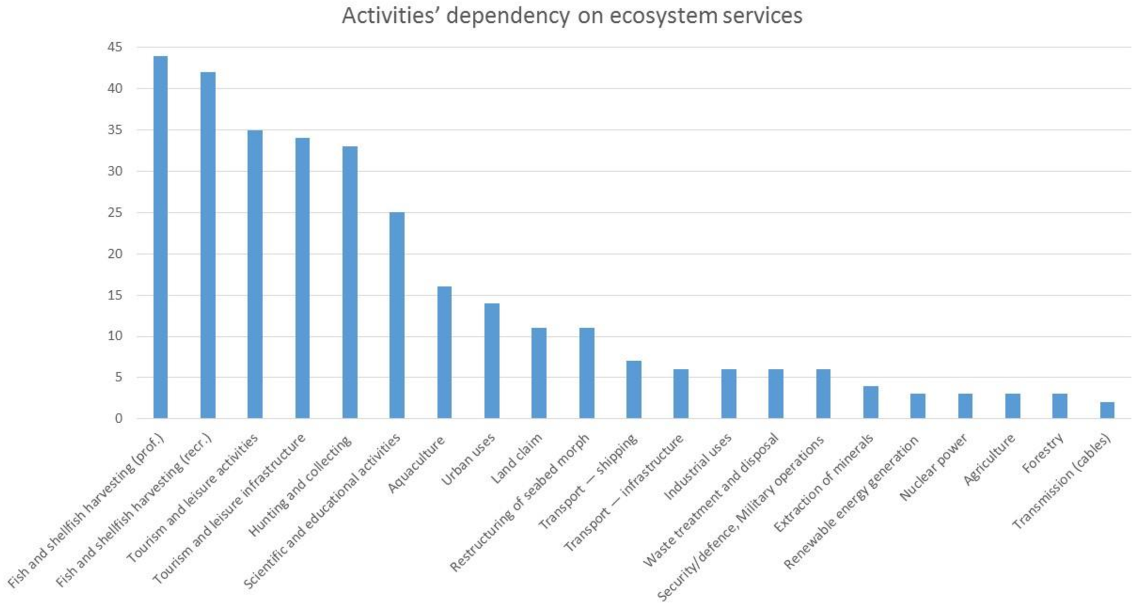

Figure 8. *Summed dependency of human activities on ecosystem services (sum-ups of rows in Table 9) which gives an indication of the relative dependency of various activities on marine ecosystem services.*

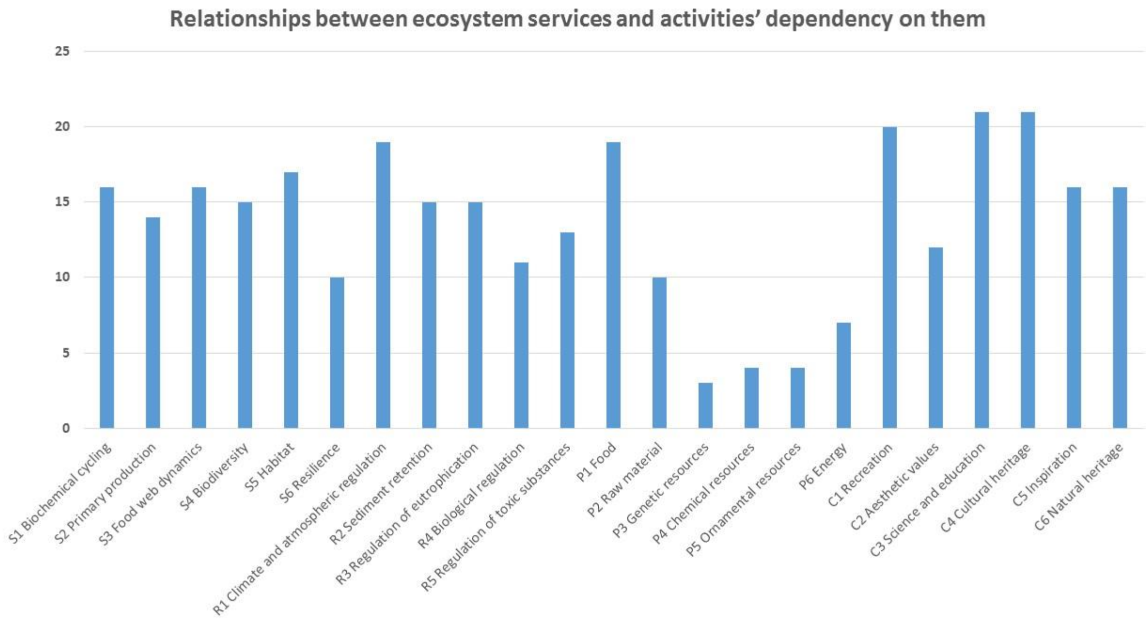

Figure 9. *Summed relationships between human activities and their dependency on ecosystem services from an ecosystem service perspective (sum-ups of columns in Table 9) which gives an indication of which marine ecosystem services that most activities are dependent on.*

Example of how the results of the assessments done above can be used (preliminary results)

As an example, applying the results from the exercises above, preliminary data from the direct/DI-method were first used to illustrate the relationship between Swedish activities at sea and marine ecosystem services for a few central activities. To indicate each dependency and negative impact of each activity on marine ecosystem services, respectively, tallied total scores may be used. The tentative results are shown in Fig. 10 and demonstrate the relationship between the activities and ecosystem services. The impact of activities on ecosystem services is indicated on the y-axis and the dependency of activities on ecosystem services on the x-axis. The economic performance of the activities is indicated by the size of the bubble, based on economic data for value added derived using the NACE codes for each activity according to Statistic Sweden.

After this initial exercise, it was chosen to run corresponding analyses also for the full data sets, i.e. to illustrate the impact of all activities (on the x-axis) and their dependency (on the y-axis) on marine ecosystem services. First this was done for the Direct/DI-method (Fig. 11) using tallied scores from Table 4 (impact) and Table 9 (dependency). Then, this was done for the Indirect/DPSI-method using impact sums (Fig. 12) and tallied sums from Table 8 (impact) and Table 9 (dependency). The position of all central human activities in the plot/graph are shown with a marker and a label telling the identity of the activity. Note that these runs could not be done in the same way for the background environmental variables, as they have no dependency on the marine ecosystem services and thus their placement is only indicated along the x-axis (always 0 for the y-axis). Note also, that the activities from Annex III in the Marine Strategy Framework Directive that were used in the Direct/DI-evaluation (Fig. 11) were not fully represented in Symphony and thus the activities had to be partly regrouped in the Indirect/DPSI-evaluation (Fig. 12) in order to get somewhat comparable figures. Still, the results deviate pretty much between Fig. 11 and Fig. 12. Also, the absence of certain activities, i.e. the ones that are missing from the Indirect/DPSI-evaluation (Fig. 12) such as recreational fishing, recreational infrastructure, nuclear power plants, agriculture, forestry, science and education as well as climate change induced lowered salinity, complicates any attempt to compare the results.

The results and approaches presented here are preliminary, and should be treated as such, but we are hopeful that the results and methods can be further evolved, and potentially be developed towards use in analysing effects on ecosystem services from changes in human activities and pressures at sea. Because of the transparency of the different steps and the possibility to include gradually improved data and knowledge, the described approach could be part of an interactive tool, also linking to marine spatial planning scenarios, to assess links between human activities management and impacts on marine ecosystem services. If combined with reliable spatial data, it should also be possible to present and apply results in the mapping of marine ecosystem services in this context.

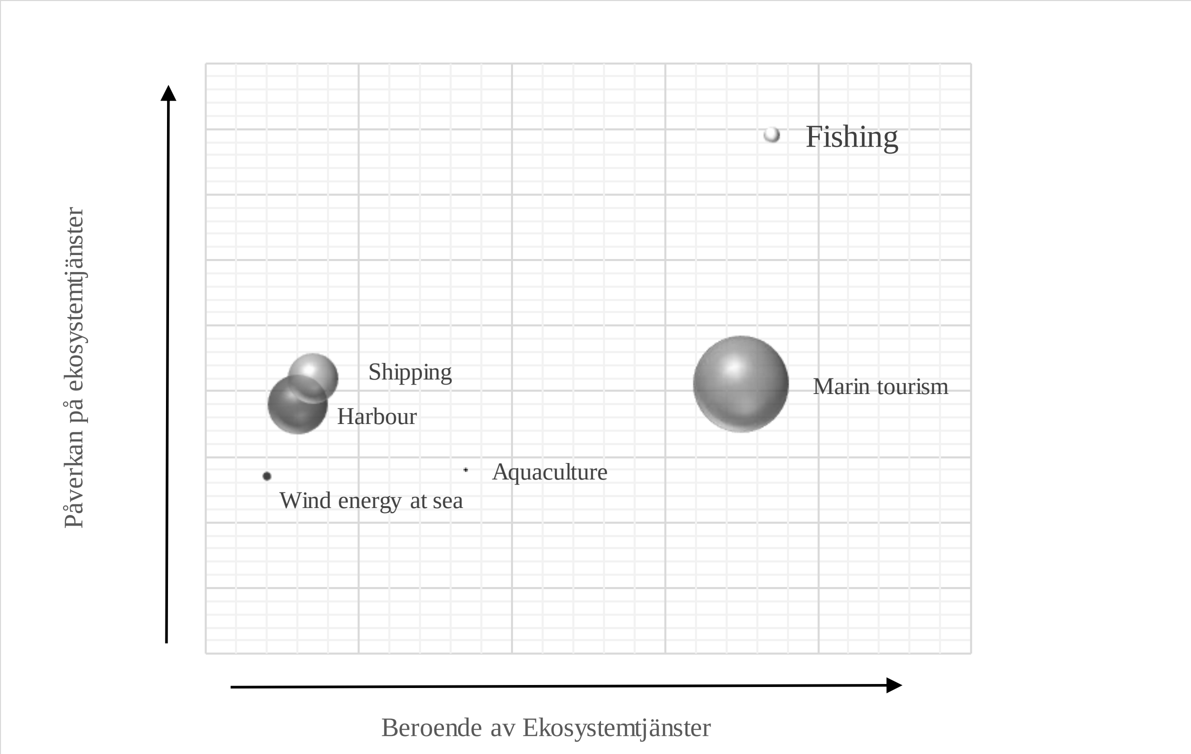

Figure 10. *Tentative results for the dependency of human marine activities on ecosystem services (x-axis) and their impact on ecosystem services (y-axis). The size of the bubbles represents their value added. The total value of all the sectors represented in the diagram is 1.5 % of the Swedish Gross Domestic Product.*

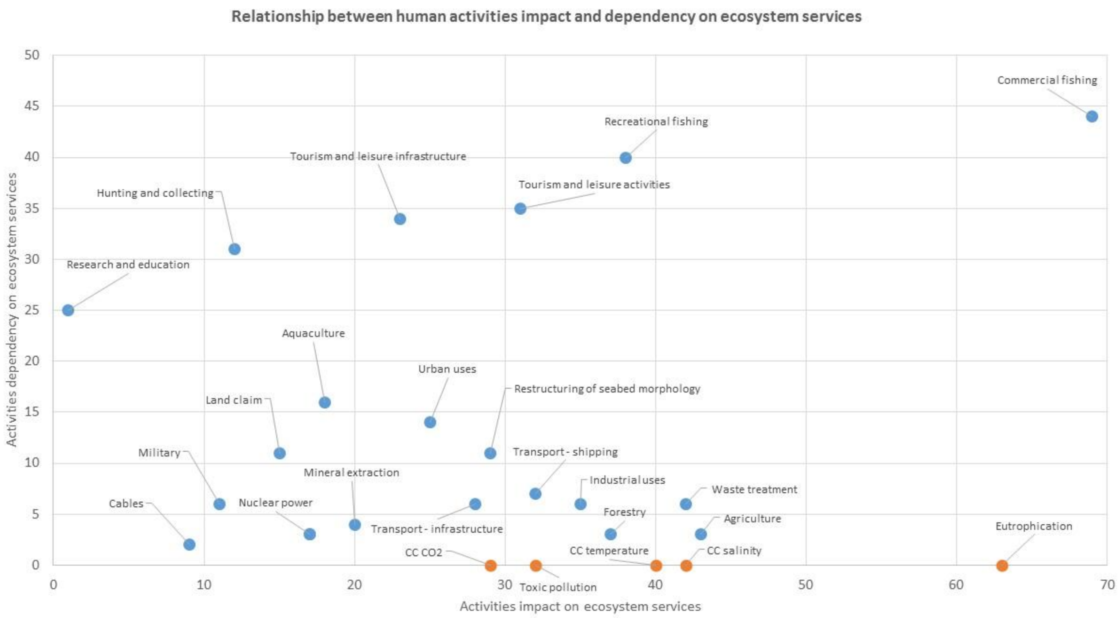

Figure 11. *Results for human marine activities dependency on ecosystem services (y-axis) and their impact on ecosystem services (x-axis) using the Direct/DI-method.*

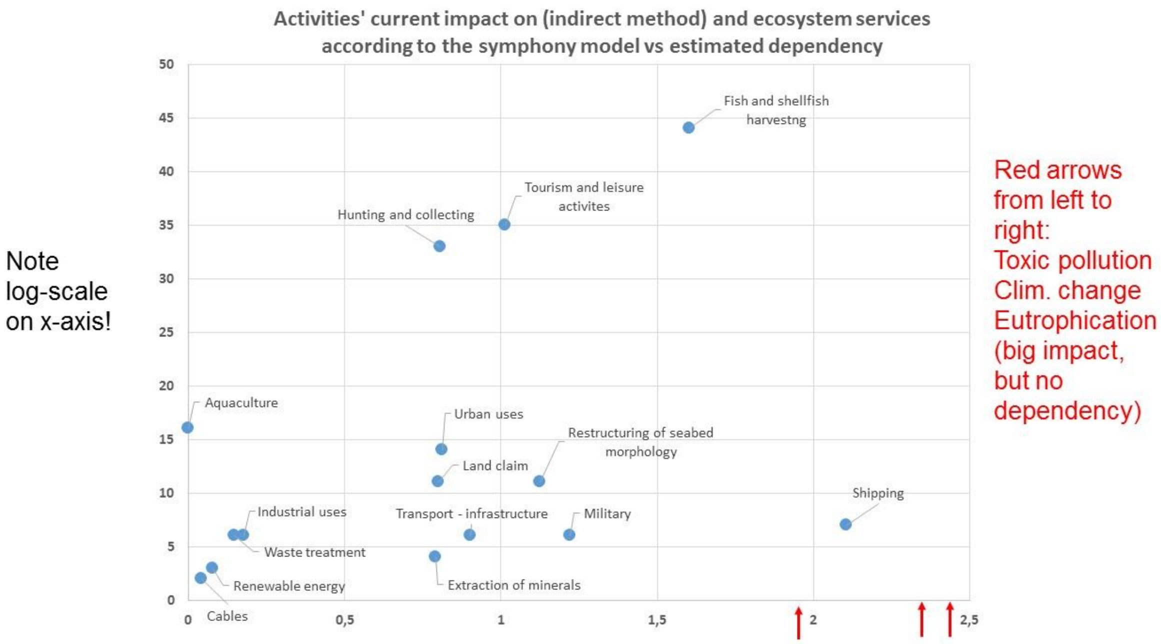

Figure 12. *Results for human marine activities' dependency on ecosystem services (y-axis) and their impact on ecosystem services (x-axis) using the Indirect/DPSI-method.*

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Appendix 1. Evaluation of the role of ecosystem components for ecosystem services using Symphony's ecosystem components

Supporting ecosystem services (the numbers given refer to scores 0–4)

S1 Biochemical cycling

- Cycles of C, P, N and O_2 are considered mainly with regard to primary producers (4 points), but also to a lesser extent for all animals by their consumption and release of feces (filter feeders, bioturbation species, herbivores, fish, birds, mammals). Animals score 1 point.
- For benthic systems, all systems are important, but we considered shallow (photic) bottom areas to have a higher degree of importance (4) than aphotic/deep ones (3) due to the generally higher production in shallow waters.
- Anoxic bottom areas are not considered explicitly!

S2 Primary production

- Primary production is strictly interpreted as the contribution from primary producers (4); no herbivory or cascading top down influence have been taken into account for the scores
- This concerns production in the photic zone (4)
- Photic transport bottom areas (with less primary producing species) slightly lower (3) than photic hard and soft bottom areas (4)
- Artificial reefs considered for the reef parts that are present in the photic zone (2)

S3 Food web dynamics

- Plankton, photic hard and soft bottom areas score 4.
- Mussels and angiosperms score 3
- Seals, fish and birds are all important (3–4) for foodweb dynamics
- Photic transport bottom areas (with less primary producing species) slightly lower (3) than photic hard and soft bottom areas (4)
- Aphotic and deep bottom areas all score 3
- Porpoise occurrence (3) scores higher than porpoise reproduction (2)
- Eel migration (referring to non-feeding silver eels passing by) is given 1

S4 Biodiversity

- Exceptionally rich species assemblages are given 4 (certain habitat formers, photic zones with generally higher primary and secondary production)
- Certain species assemblages (wintering birds) are given 3
- Species with stronger influence on other species are given 2. This number also for aphotic and deeper bottom areas with lower production
- All single species are given at least 1
- Zeros can be given for non-indigenous species

S5 Habitat

- Habitat forming species and photic bottom areas with species rich assemblages and generally higher primary and secondary production are given 4
- Reproduction (porpoise, birds), spawning (fish), river mouth fish and overwintering areas (birds), i.e. ecosystem components representing habitats for these speices are also given 4
- Aphotic and deeper bottom areas with lower production are given 2
- No habitat function present for porpoise, seals and fish species, thus 0

S6 Resilience

- 3–4 is given for habitat forming species and photic bottom areas with species rich assemblages and generally higher primary and secondary production as well as for cod
- All single species are given at least 2, this number also for aphotic and deeper bottom areas with lower production
- 0 is given for artificial substrates which take up space from natural habitats and thus cannot be considered to contribute to resilience

Regulating ecosystem services (the numbers given refer to scores 0–2)

R1 Climate and atmospheric regulation

- 2 for plankton communities and angiosperms as well as for photic bottom areas
- 1 for mussel reefs, artificial reefs and for aphotic and deep soft bottom areas (the latter have a role as accumulation bottom areas)
- 0 for all animals and for deep bottom areas

R2 Sediment retention

- Vegetation and molluscs act against erosion and so do reefs and accumulation (soft) bottom areas, 2 for these components
- Deep reefs, artificial reefs and photic transport bottom areas receive 1
- 0 for all the rest such as single animal species, plankton and aphotic and deep hard and transport bottom areas

R3 Regulation of eutrophication

- Highest scores, 2, for uptake of nutrients in organisms that are harvested (fish, mussels) and contribute to top down regulation, but also for perennial algae and plants (photic bottom areas) and for aphotic and deep soft bottom areas (sediment binding on accumulation bottom areas). To a great extent, a bottom-up thinking has been adapted when giving the scores
- 1 for aphotic and deep hard bottom areas and all transport bottom areas as well as for fish spawning areas
- 0 for porpoise, seals and birds (highest level top predators, which have less influence than top predatory fish)

R4 Biological regulation

- 2 for mussels, cod and spawning fish (pike and perch) and river mouth fish capable of imposing this kind of regulation (herbivory, filter feeding and top down control), much more of a top-down thinking in comparison to R3
- 1 for photic bottom areas and the like (reefs) as well as for all soft bottom areas, angiosperms and herring
- 0 for porpoise, seals and birds (highest level of top predators which have less influence than top predatory fish), 0 also for sprat and vendace as well as for the aphotic and deep hard and transport bottom areas

R5 Regulation of toxic substances

- 2 for organisms that are harvested such as mussels and fish
- 2 also for soft bottom areas where toxic substances are accumulated
- 1 for other bottom areas and reefs (except for aphotic and deep hard and transport bottom areas)
- 1 also for angiosperms, fish spawning areas and eel migration
- 0 for porpoise, seals and birds
- 0 also for the aphotic and deep hard and transport bottom areas

Provisioning ecosystem services

P1 Food

- 2 for organisms that are harvested as food such as mussels and fish, 2 for the habitats for the food species
- 1 for plankton
- 0 for porpoise, seals, birds, angiosperms and artificial reefs

P2 Raw material

- This concerns exclusively biological raw material
- 2 for herring and sprat (industrial feed fishing)
- 1 for mussels (fertilizer/feed), plankton and angiosperms (isolation/building material) as well as for benthic habitats in general
- 0 for porpoise, seals, birds, deep reefs, haploops reefs, artificial reefs and for fish species used for food

P3 Genetic resources

- 2 for ecosystem components representing several species (an assemblage in a habitat)
- 1 for ecosystem components representing just one species
- No zeros

P4 Chemical resources

- 1 for mussels (glue, rust protection), plankton (antioxidants and food supplements), cod (cod liver oil), herring/sprat (omega 3) as well as for hard and soft bottom photic zone in general
- 0 for porpoise, seals, birds, deep reefs, haploops reefs, aphotic and deep bottom areas, artificial reefs, angiosperms and for most fish species

P5 Ornamental resources

- 1 for shells from molluscs and starfish on photic bottom areas and reefs (habitats producing this service), bird feathers from birds coastal and from wintering birds coastal (0 for winter offshore birds)
- 0 for all other ecosystem components

P6 Energy

- Concerns the biomaterial used for energy – bioenergy
- 1 for mussels, plankton, fish waste, tunicates as well as for bottom areas producing these resources in accessible depths
- 0 for all other ecosystem components

Cultural ecosystem services

C1 Recreation

- 2 for fish/fishery activities and for charismatic species as well as for shallow (more easily accessed) hard bottom areas including artificial reefs), 2 also for angiosperms and mussel reefs.
- 1 for photic transport and soft bottom areas
- 0 for deeper and inaccessible bottom areas

C2 Aesthetic values

- 2 for charismatic species such as porpoise, seals, birds, mussel reefs, photic hard bottom areas, angiosperms and river mouth fish
- 1 for artificial reefs, photic transport and soft bottom areas and all fish species
- 0 for deeper and inaccessible bottom areas

C3 Science and education

- 2 for charismatic species worth bringing forward for both scientific and educational purposes
- 1 for all the remaining ecosystem components (merely of academic interest)
- No zeros

C4 Cultural heritage

- 2 for fish and bird species (traditional life by the coast)
- 1 for mammals and photic habitats and also for artificial substrates (ship wrecks)

- 0 for deeper and inaccessible bottom areas, historically poorly known

C5 Inspiration

- 2 for charismatic species such as porpoise, seals, cod, river mouth fish and birds
- 1 for reproduction and spawning areas and other organisms
- 0 for deeper and inaccessible bottom areas, less known

C6 Natural heritage

- 1 for all named species and for the photic habitats
- 0 for deeper and inaccessible bottom areas, less known

Appendix 2. Evaluation of the role of ecosystem components for ecosystem services using BALTIC SEA IMPACT INDEX ecosystem components

Supporting ecosystem services (the numbers given refer to scores 0–4)

S1 Biochemical cycling

- Cycles of C, P, N and O_2 are considered mainly with regard to primary producers (4 points), but also to a lesser extent for all animals by their consumption and release of feces (filter feeders, bioturbation species, herbivores, fish, birds, mammals). Animals score 1 point.
- For benthic systems, all systems are important, but we considered shallow (photic) bottom areas to have a higher degree of importance (4) than aphotic/deep ones (3) due to the generally higher production in shallow waters.
- Anoxic bottom areas are not considered explicitly!
- All Natura habitats scored 3
- Migratory routes for birds scored 0

S2 Primary production

- Primary production is strictly interpreted as the contribution from primary producers (4), no herbivory or cascading top down influence have been taken into account for the scores
- This concerns production in the photic zone (4)
- Photic transport bottom areas (with less primary producing species) slightly lower (3) than photic hard and soft bottom areas (4)
- All Natura habitats scored 3. Also sand banks and sand/mud flats can be quite important for primary production through microalgae, diatoms, etc.
- Infralittoral bottom areas closer to the surface scored higher (4) than circalittoral bottom areas (3), the latter refer to bottom areas below the infralittoral ones, but still being photic.

S3 Food web dynamics

- Plankton, photic hard and soft bottom areas all score 4
- Seals, fish and birds are all important (3–4) for food web dynamics: higher for occurrence than for recruitment areas
- Photic transport bottom areas (with less primary producing species) slightly lower (3) than photic hard and soft bottom areas (4)
- All Natura habitats scored 3
- *Chara*, *Fucus*, *Zostera*, *Mytilus* and *Furcellaria* all score 3
- Aphotic and deep bottom areas all score 3
- Porpoise occurrence (3) scores higher than porpoise reproduction (2), seal occurrence (3) scored higher than seal haulouts (2) (haulouts were here considered merely as reproduction and absence from the water)
- No 1 or 0

S4 Biodiversity

- Exceptionally rich species assemblages are given 4 (certain habitat formers, photic zones with generally higher primary and secondary production)
- All Natura habitats scored 4
- Diverse species assemblages (wintering and migrating birds) are given 3
- Aphotic and deeper bottom areas with lower production are also given 3
- Species with evident influence on other species, such as predators and herbivores, are given 2.
- All single species are given at least 1
- No zeros (but zeros would be given for non-indigenous species)

S5 Habitat

- Habitat forming species and photic bottom areas with species rich assemblages and generally higher primary and secondary production are given 4
- Reproduction (porpoise, birds), spawning (fish), haulouts (seals) and overwintering and migrating areas (birds) are given 4
- All Natura habitats scored 4
- Aphotic and deeper bottom areas with lower production are given 2
- No habitat function present for porpoise, seals and fish species, thus 0

S6 Resilience

- 3–4 is given for habitat forming species and photic bottom areas with species rich assemblages and generally higher primary and secondary production as well as for cod
- Infralittoral bottom areas closer to the surface scored higher (4) than circalittoral bottom areas deeper down in the photic zone (3)
- All Natura habitats scored 4, with the exception of sandbanks (1110) and mud- and sandflats (1130) which scored 3
- All single species are given at least 2, this number also for aphotic and deeper bottom areas with lower production
- No 1 and 0

Regulating ecosystem services (the numbers given refer to scores 0–2)

R1 Climate and atmospheric regulation

- 2 for plankton communities and angiosperms as well as for photic bottom areas
- All Natura habitats also scored 2
- 1 for mussel reefs and for oxygenated deep bottom areas (the latter have a role as accumulation bottom areas)
- 0 for all animals

R2 Sediment retention

- Vegetation and molluscs act against erosion and so do reefs and oxygenated deep bottom areas, 2 for these components
- All Natura habitats also scored 2
- 0 for all the rest such as surface waters (plankton) and single animal species

R3 Regulation of eutrophication

- Highest scores, 2, for uptake of nutrients in organisms that are harvested (fish, mussels) and contribute to top down regulation, but also for perennial algae and plants (photic bottom areas) and for oxygenated deep bottom areas (sediment binding on accumulation bottom areas). To a large extent, a bottom-up thinking has been adapted when giving the scores
- All Natura habitats also scored 2
- 1 for fish spawning areas, e.g. flounder, 1 for roach which is a mesopredator and thus has a less influential regulating role
- 0 for porpoise, seals and birds (highest level top predators, which have less influence than top predatory fish)

R4 Biological regulation

- 2 for mussels, cod and spawning fish capable of imposing this kind of regulation (herbivory, filter feeding and top down control), much more of a top-down thinking in comparison to R3
- 2 for the following Natura habitats: Estuaries (1130), coastal lagoons (1150) and large shallow inlets and bays (1160), 1 for all other Natura habitats
- 1 for photic bottom areas and the like (reefs) as well as for all soft bottom areas; and herring and roach which are mesopredators and thus have a less influential regulating role
- 1 for seals, 0 for seal haulouts
- 1 for flounder (mesopredator of soft bottom areas)
- 0 for porpoise, sprat and birds (highest level of top predators which have less influence than top predatory fish), 0 also for the aphotic and deep hard and transport bottom areas

R5 Regulation of toxic substances

- 2 for organisms that are harvested such as mussels and fish
- 2 also for soft bottom areas where toxic substances are accumulated
- 2 for the following Natura habitats: Estuaries (1130), coastal lagoons (1150) and large shallow inlets and bays (1160), 1 for all other Natura habitats
- 1 for other bottom areas and reefs (except for deep bottom areas)
- 1 also for angiosperms, flounder and roach spawning areas
- 0 for porpoise, seals and birds

Provisioning ecosystem services

P1 Food

- 2 for organisms that are harvested as food such as mussels and fish + their spawning and recruitment areas (2 for habitats for food species)
- 1 for all Natura habitats
- 1 for plankton, 1 for roach
- 0 for porpoise, seals and birds

P2 Raw material

- This concerns exclusively biological raw material
- 2 for herring and sprat (feed fishing)
- 1 for mussels (fertilizer/feed), plankton and angiosperms/*Zostera* (isolation/building material) as well as for benthic habitats in general
- 1 for all Natura habitats
- 0 for porpoise, seals and birds and for fish species used for food

P3 Genetic resources

- 2 for ecosystem components representing several species (an assemblage in a habitat)
- 2 for all Natura habitats
- 1 for ecosystem components representing just one species
- No zeros

P4 Chemical resources

- 1 for mussels (glue, rust protection), plankton (antioxidants and food supplements), cod (cod liver oil), herring/sprat (omega 3) as well as for hard and soft bottom photic zone in general
- 1 for all Natura habitats
- 0 for porpoise, seals, birds, deep waters and for most fish species
- No component received score 2

P5 Ornamental resources

- 1 for shells from molluscs and starfish on photic bottom areas and reefs (habitats producing this service), bird feathers (which is why birds get 1 for breeding and wintering areas, but 0 for migration routes)
- 1 for all Natura habitats as they all to some extent support organisms providing this service
- 0 for all other ecosystem components
- No component received score 2

P6 Energy

- Concerns the biomaterial used for energy – bioenergy
- 1 for mussels, plankton, fish waste, tunicates as well as for bottom areas producing these resources at accessible depths
- 1 for all Natura habitats as they all to some extent support organisms providing this service
- 0 for all other ecosystem components
- No component received score 2

Cultural ecosystem services

C1 Recreation

- 2 for fish/fishery activities and for charismatic species as well as for shallow (more easily accessed) hard bottom areas
- 2 for *Zostera*, *Chara*, *Fucus* and for *Mytilus* reefs
- 2 for all Natura habitats, except sandbanks (1110), mud- and sandflats (1130) and submarine structures made by leaking gas (1180) which scored 1
- 1 for photic sandy and muddy bottom areas
- 0 for surface waters and deeper more inaccessible bottom areas
- 0 for roach

C2 Aesthetic values

- 2 for charismatic species such as porpoise, seals, birds, mussel reefs, photic hard bottom areas
- 2 for *Zostera*, *Chara*, *Fucus* and for *Mytilus* reefs
- 2 for all Natura habitats, except sandbanks (1110), mud- and sandflats (1130) and submarine structures made by leaking gas (1180) which scored 1
- 1 for photic sandy and muddy bottom areas and all fish species
- 0 for surface waters and deeper more inaccessible bottom areas

C3 Science and education

- 2 for charismatic species worth bringing forward for both scientific and educational purposes
- 2 for all Natura habitats
- 1 for all the remaining ecosystem components (merely of academic interest)
- No zeros

C4 Cultural heritage

- 2 for fish and bird species (traditional life by the coast)
- 1 for mammals and bottom habitats
- 1 for all Natura habitats
- 0 for deep inaccessible bottom areas, historically poorly known

C5 Inspiration

- 2 for charismatic species such as porpoise, seals, birds and cod
- 1 for reproduction and spawning areas and other organisms
- 1 for all Natura habitats
- No zeros

C6 Natural heritage

- 2 for some Natura habitats which could be considered as Baltic Sea heritage, characteristic and/or scenic landscapes and formations
- 1 for all named species and for the photic habitats
- 0 for deep inaccessible bottom areas, less known…