Havs
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An ecosystem service approach for analyzing marine human activities in Sweden

A synthesis for the Economic and Social Analysis of the Initial Assessment of the Marine Strategy Framework Directive

Havs- och vattenmyndighetens rapport 2012:8

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Enveco Environmental Economics Consultancy
(Tore Söderqvist, Linus Hasselström and Åsa Soutukorva)
EnviroEconomics Sweden
(Scott Cole)
IVL Swedish Environmental Research Institute
(Mikael Malmaeus)

with contributions from
DHI Sweden
(Patricia Moreno-Arancibia, Olof Liungman and Nick Ahrensberg)
IVL Swedish Environmental Research Institute
(Jonas Fejes, Erik Fridell, Mattias Gustafsson, Maria Lindblad, Susanna Roth, Peter Stigson, Johan Stål, Annika Tegeback, Philip Thörn, Ida Westerberg and Hulda Winnes)

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Foreword

Within Europe, the efforts to implement new legislation around the marine environment have begun in earnest. In order to gather all maritime activities into a single framework, the EU has formulated a maritime strategy designed after three main directions: the Common Fisheries Policy, marine spatial planning, and common environmental legislation for the marine environment. The common environmental legislation has been formulated within the EU Marine Strategy Framework Directive (2008/56/EG) which was introduced into Swedish legislation through the Marine Environmental Regulation (SFS 2010:1341).

In Sweden, marine issues received a new home on 1 July 2011 with the creation of a new, central administrative authority, the Swedish Agency for Marine and Water Management (SwAM). The new agency will use an integrated approach in working with issues pertaining to water, marine, and fisheries management. The introduction of the Marine Strategy Framework Directive (MSFD) in Sweden and the development of marine spatial planning will become central to operations in the coming years.

As a first step in Sweden's work with MSFD, an initial assessment of the marine environment's status has been conducted and assembled into "Good Environmental Status 2020 – Part 1: Initial Assessment of the State of the Environment and Socio-economic Analysis." As the name suggests, the assessment gives an overall picture of the current state of the environment. It also describes the socio-economic importance of the different activities and operations currently in progress in marine areas as well as the stresses they generate on the ecosystem.

The report "*An ecosystem service approach for analyzing marine human activities in Sweden"* is an important part of the documentation produced by the Swedish Agency for Marine and Water Management for the initial assessment. The report deals with the socio-economic analysis and addresses how different activities in Swedish marine waters are dependent on ecosystem services, and at the same time affect the ability of the ecosystems to provide the same services. In addition, the report gives an assessment of the socio-economic cost that can be expected as a result of a continued degradation of the marine environment. The report is a summary of four previous reports (dealing with the Swedish maritime sector, the Swedish marine tourism and recreation sector, oil spills in Swedish marine waters and marine litter) commissioned by SwAM and the Swedish Environmental Protection Agency to underpin the Swedish initial assessment.

Mats Ivarsson, December 2012

Förord

I Europa har arbetet med att genomföra ny lagstiftning på havsmiljöområdet inletts på allvar. Med syfte att samla all maritim verksamhet i ett och samma ramverk har EU formulerat en maritim strategi som utformats efter tre huvudriktningar; gemensam fiskeripolitik, fysisk planering till havs samt gemensam miljölagstiftning för den marina miljön. Den gemensamma miljölagstiftningen har formulerats i Havsmiljödirektivet (2008/56/EG) som omsatts i svensk lag genom Havsmiljöförordningen (SFS 2010:1341).

I Sverige fick de marina frågorna en ny hemvist 1:e juli 2011 genom inrättandet av en ny central förvaltningsmyndighet, Havs- och vattenmyndigheten. Den nya myndigheten ska arbeta på ett integrerat sätt med vatten-, havs och fiskförvaltningsfrågor. Införandet av havsmiljödirektivet i Sverige, samt utvecklingen av den marina fysiska planeringen kommer att vara centrala delar av verksamheten under de kommande åren.

Som ett första steg i det svenska arbetet med Havsmiljödirektivet har en inledande bedömning av havsmiljöns tillstånd gjorts, *God miljöstatus 2020 – Del 1: Inledande bedömning av miljötillståndet och socioekonomisk analys*. Som namnet antyder ger den inledande bedömningen en bild av det nuvarande miljötillståndet. Den beskriver också den samhällsekonomiska betydelsen av olika aktiviteter och verksamheter som pågår i våra havsområden idag, samt den belastning på ekosystemen som nyttjandet ger upphov till.

Rapporten *An ecosystem service approach for analyzing marine human activities in Sweden* är en viktig del i det underlag som tagits fram av Havs – och vattenmyndigheten för den inledande bedömningen. Rapporten behandlar den samhällsekonomiska analysen och beskriver dels hur olika aktiviteter i svenska marina vatten är beroende av ekosystemtjänster, och dels hur samma aktiviteter påverkar ekosystemtjänsternas förmåga att leverera nyttor till samhället. I tillägg ges en beskrivning över hur samhället kommer att påverkas om miljöförsämringarna i de marina miljöerna fortsätter. Rapporten sammanfattar fyra underlagsrapporter (om den maritima sektorn, marint avfall, oljespill och marin turism och rekreation) som tagits fram på uppdrag av Havs- och vattenmyndigheten och Naturvårdsverket för den inledande bedömningen.

Mats Ivarsson, december 2012

INNEHÅLL

0 Summary

The initial assessment (IA) of the implementation of the EU Marine Strategy Framework Directive (MSFD) includes an economic and social analysis (ESA). This analysis covers two components: (1) the use of marine waters and (2) the cost of degradation of the marine environment. The Swedish ESA work has entailed four different areas, reported in four separate reports:

A. The maritime sector (IVL and Enveco, 2012 "Report A")
B. Marine tourism and recreation (Enveco, DHI and Resurs, 2012 "Report B")
C. Oil spill (IVL, Enveco and EnviroEconomics Sweden, 2012 "Report C")
D. Marine litter (Enveco and DHI, 2012 "Report D")

The purpose of this analysis is to synthesize the results of the four reports.

The Swedish ESA is based on the ecosystem service approach and also on the DPSIR framework for sorting out relationships between Drivers, Pressures, State, Impact and Response. The point of departure in terms of marine ecosystem services is the classification in Table 0.1. We apply an ecosystem service analysis that in principle follows the procedure of a Corporate Ecosystem Services Review (ESR) (WRI, 2008) for evaluating a human activity's dependence of – and impact on – eco system services. In the DPSIR context, the focus is on both how a driver influences the status of ecosystem services through its pressure and how the driver is affected by the status of ecosystem services. In short, this analysis applies the following four steps:

I. Identify the human activities, i.e. the drivers.

II. Identify associated pressure (for each driver) and determine (1) which ecosystem service(s) it is mainly dependent upon and (2) which ecosystem services it mainly affects. Based on this "filter", select the most relevant ecosystem services for further analysis.

III. Analyze the status and trends in the selected ecosystem services by associating them to Good Environmental Status (GES) descriptors and indicators.

IV. Analyze how a business-as-usual (BAU) scenario influences the trend in GES indicators and thus, the implied status of ecosystem services.

Figure 0.1 describes the analysis of the report in a DPSIR framework. Areas A and B have been included as the drivers subject to study. Thus, we investigate the dependence of these human activities on ecosystem services (i.e., the dashed arrow from impacts to drivers). As to pressures, areas C (oil spill) and D (marine litter) constitute two types of pressures from areas A and B, although other pressures from areas A and B are also studied, as shown in Figure 0.1. Because some important drivers influencing the marine environment are not taken into account in the analysis (e.g. agriculture and non-maritime industry), this synthesis may provide an incomplete picture of the total pressure on the marine environment and thus on the supply of marine ecosystem services.

Table 0.1. List of identified marine ecosystem services provided by the Baltic Sea and the Skagerrak (S=supporting, R=regulating, P=provisioning, C=cultural). See Appendix A for detailed definitions of the services. Source: Garpe (2008) and SEPA (2009).

	Ecosystem service	**Brief definition** (after Garpe, 2008)
S1	Biogeochemical cycling	Maintenance of the cyclical movement of energy and materials within ecosystems.
S2	Primary production	The conversion of dead material (inorganic) to living material (organic) by means of phytosynthesis.
S3	Food web dynamics	Maintenance of who-eats-who (trophic) relationships among organisms.
S4	Diversity	Maintenance of the variety in genes, species, ecosystems and ecosystem functions.
S5	Habitat	Maintenance of the environments in which organisms live.
S6	Resilience	Maintenance of the extent to which ecosystems can absorb perturbations and continue to regenerate without degrading.
R1	Climate and atmospheric regulation	Maintenance of the chemical composition of the atmosphere and ocean.
R2	Sediment retention	Ecosystems' stabilization and retention of sediments, thus mitigating coastal erosion.
R3	Eutrophication mitigation	Ecosystems' removal of excess nitrogen and phosphorus.
R4	Biological regulation	Organisms' regulation of the abundance of other organisms, e.g. pests and pathogens.
R5	Regulation of hazardous substances	Breaking down, storing and burying of toxic substances and societal waste.
P1	Food	Provision of fish and other food fit for human consumption.
P2	Inedible goods	Provision of marine products not used as food for humans, e.g. fish meal and sand extraction.
P3	Genetic resources	Provision of marine genetic resources of actual or potential value.
P4	Chemical resources	Provision of marine resources for pharmaceutical, chemical and biochemical use.
P5	Ornamental resources	Provision of marine products for the purpose of decoration or handicraft, e.g. amber.
P6	Energy	Acquisition of energy directly from the marine environment.
P7	Space and waterways	Provision of the sea surface as a medium for e.g. transports, site for energy provisions and other constructions.
C1	Enjoyment of recreational activities	Provision of opportunities to have different types of recreation and tourism.
C2	Scenery	Provision of opportunities to enjoy aesthetic values including the appreciation of beauty and silence.
C3	Science and education	Provision of opportunities to have educational activities and research.
C4	Cultural heritage	Provision of opportunities to use the marine and coastal environment for spiritual, sanatory or historical purposes.
C5	Inspiration	Provision of opportunities to inspire art and advertisement.
C6	The legacy of the sea	The appreciation of the marine and coastal environment nature for ethical (non-use) reasons.

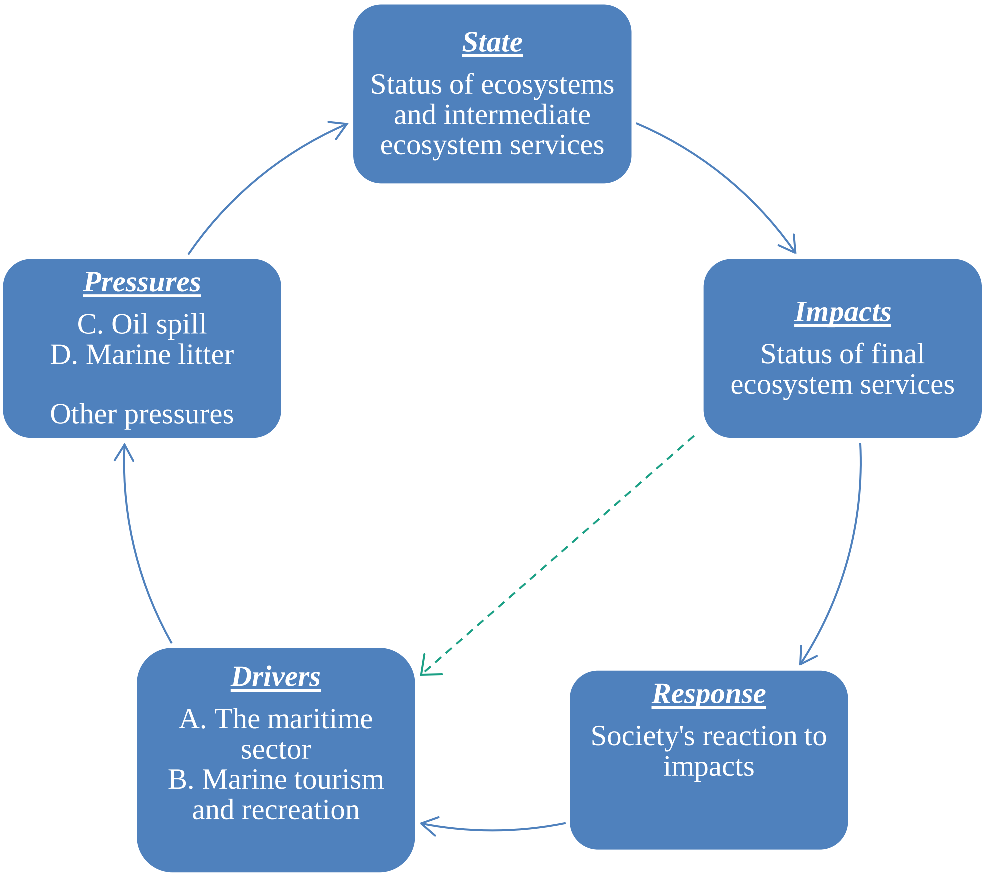

Figure 0.1. Areas A-D in the DPSIR framework.

Table 0.2 summarizes how the main drivers in this synthesis are *dependent* upon marine ecosystem services (X axis of the table). Table 0.3 describes the main *impacts* of these drivers on the supply of marine ecosystem services (Y axis of the table). Note that the categorization of drivers is somewhat different in these two tables. Based on our ESR approach, we select three ecosystem services for further analysis from Table 0.3. The services that we determine to be the most relevant for in-depth study include:

- S4 Diversity
- R3 Eutrophication mitigation
- C2 Scenery

Table 0.2. Main dependencies of sectors on marine ecosystem services

Sec- tors	**Ecosystem services**																	
	S1- S6, R1	**R2**	**R3**	**R4**	**R5**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
	Supp & cli. atm. reg.	**Sed reg**	**Eutr mit**	**Bio reg**	**Reg haz sub**	**Food**	**Ined good s**	**Gen res**	**Che res**	**Orn res**	**Energ y**	**Spa- ce & w w**	**Recr**	**Sce- nery**	**Sci & edu**	**Cul her**	**Inspi- ration**	**Le- gacy of sea**
A.a												Final						
A.b	Fu											Final						
A.c	Fu		I for P1	I for P1	I for P1	Final						Final						
Recr. fish.	Fu		I for P1	I for P1	I for P1	I for C1						Final	Final	I for C1		I for C1		
B.a-B.e	Fu		I for C1									Final	Final	I for C1		I for C1		
B.f-B.h	Fu		I for C1		I for C1								Final	I for C1		I for C1		

Fu = fundamental marine ecosystem service
I = intermediate marine ecosystem service
Final = final marine ecosystem service
A.a = maritime transports and port activities
A.b = maritime energy sector
A.c = commercial fisheries and aquaculture
Recr. fish. = recreational fisheries (a component in B.e-B.h)
B.a-B.e = marine tourism and recreation focusing on the use of ships/boats
B.f.-B.h = marine tourism and recreation not focusing on the use of ships/boats

Table 0.3. Main impact of human activities on the supply of marine ecosystem services (as screened in the different reports).

Ecosystem services		Maritime transport and port activities, incl. marine tourism and recr. focusing on the use of ships/boats	Maritime energy sector	Fisheries and aquaculture	Marine tourism and recreation not focusing on the use of ships/boats
S1	Biogeochemical cycling				
S2	Primary production	+		+	+
S3	Food web dynamics				
S4	Diversity	-	-	-	
S5	Habitat	-	-	-	
S6	Resilience	-			
R1	Climate and atmospheric regulation	+		+	
R2	Sediment retention	-	-	-	
R3	Eutrophication mitigation	-		-	-
R4	Biological regulation			+	
R5	Regulation of hazardous substances	+ and -		+ and -	-
P1	Food	-	-	+ and -	
P2	Inedible goods	+		+ and -	
P3	Genetic resources	-		-	
P4	Chemical resources	-			
P5	Ornamental resources				
P6	Energy				
P7	Space and waterways				
C1	Recreation	-	-	-	-
C2	Scenery	-	-	-	-
C3	Science and education				
C4	Cultural heritage				
C5	Inspiration	-			
C6	The legacy of the sea	-		-	-

We link these three ecosystem services (S4 Diversity, R3 Eutrophication mitigation and C2 Scenery) to the most relevant GES descriptors and indicators, as shown in Table 0.4. In terms of descriptors, S4 was found to be most closely connected to GES descriptor D1 Biological diversity, R3 to D5 Eutrophication and C2 to D8 Contaminants and D10 Marine litter. The next step was to determine which GES indicators most influence the status of the three selected ecosystem services, also shown in Table 0.4. Finally, based on our analysis of the current trends of the selected indicators we determine that the current supply of S4 and R3 are *insufficient* and the current supply of C2 to be *locally insufficient*.

Table 0.4. List of selected indicators influencing the status of the ecosystem services.

GES descriptor	Ecosystem service	Selected indicator
D1 Biological diversity	S4 Diversity	1.1.1 Distributional range
		1.2.1 Population abundance and/or biomass, as appropriate
		1.6.1 Condition of the typical species and communities
		1.6.2 Relative abundance and/or biomass, as appropriate
		1.6.3 Physical, hydrological and chemical conditions
D5 Eutrophication	R3 Eutrophication mitigation	5.1.1 Nutrients concentration in the water column
		5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities
D8 Contaminants	C2 Scenery	8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution
D10 Marine litter	C2 Scenery	10.1.1 Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source

As a first step toward projecting future supply scenarios for the selected ecosystem services to 2020 and 2050 under BAU, we review existing policies that target the relevant drivers and describe why existing policies are insufficient for reaching GES. Next, we assess qualitatively the drivers' influence on pressures in BAU to 2020 and 2050, which provides the basis for evaluating the probable development of the selected GES indicators to 2020 and 2050 and its consequences for the supply of ecosystem services. We conclude that S4 Diversity and R3 Eutrophication mitigation are likely to remain *insufficient* and S2 Scenery to remain *locally insufficient* in 2020 as well as in 2050. While GES is currently not defined quantitatively, our results nonetheless suggest that there will be a cost of degradation in the periods to 2020 and to 2050. We review existing economic studies to assess the state of information and what is required to develop a quantitative cost of degradation analysis. We find that there are some useful cost estimates for e.g. changes in fish catches, eutrophication effects, recreational opportunities and presence of marine litter. However, substantial data gaps exist. The fact that GES is unlikely to be reached in 2020 or in 2050 implies a need for new and improved policies. Examples of such policies are found in the report.

1 Introduction

The initial assessment (IA) of the implementation of the EU Marine Strategy Framework Directive (MSFD) includes an economic and social analysis (ESA). This analysis covers two areas: (1) the use of marine waters and (2) the cost of degradation of the marine environment. The Swedish ESA work has entailed four different areas:

A. The maritime sector
B. Marine tourism and recreation
C. Oil spill
D. Marine litter

Each of these areas has been subject to a separate report:

A. IVL and Enveco (2012)
B. Enveco, DHI and Resurs (2012)
C. IVL, Enveco and EnviroEconomics Sweden (2012)
D. Enveco and DHI (2012)

In this report, these reports will be referred to as the A, B, C and D reports, respectively. "The ABCD reports" will be used as a shorthand for referring to all four reports.

Because the four areas are interlinked and because the work for all four reports was carried out more or less simultaneously during July 2011-January 2012, the analyses in these reports are partly complementary and partly overlapping. In addition, the approaches chosen in the analyses were not entirely homogenous. Thus, the purpose of this analysis is to synthesize the results of the four reports.

This report is structured as follows. Chapter 2 presents the methods for the analysis. Chapter 3 identifies the relevant human activities and the resulting limitations of the analysis. An ecosystem service analysis is carried out in Chapter 4. This analysis screens out a few ecosystem services, which are subject to an in-depth analysis in Chapter 5 by linking them to GES descriptors and indicators as defined in COM (2011). Chapter 5 also contains an assessment of the current status of the selected ecosystem services. In Chapter 6, we review existing policies and policy instruments for the human activities covered by the synthesis. Chapter 6 also summarizes projections to 2020 and 2050 for the development of these human activities in a business-as-usual scenario, and reviews the consequences for GES indicators and associated ecosystem services due to this development. This provides a basis for discussing the cost of degradation in Chapter 6. Finally, a concluding discussion is found in Chapter 7.

2 The ecosystem service approach

2.1 What are marine ecosystem services?

Ecosystems provide support to human life and contribute to human well-being in numerous different ways. In recent years, this fact has increasingly been conceptualized by using the terms "ecosystem goods" and "ecosystem services", and a number of definitions and classifications are available in the literature, see TEEB (2010, p. 17) for references. The Millennium Ecosystem Assessment (MA, 2005) provided a definition and categorization that has been much employed, also by Garpe (2008) and SEPA (2009) for the case of marine ecosystems. Sometimes a distinction between "ecosystem goods" and "ecosystem services" is made, with the former referring to products that are provided by ecosystems and that usually can be traded on a market – fish is a typical example. However, we follow Garpe (2008) and SEPA (2009) and use "ecosystem services" as a general term also covering "ecosystem goods".

The concept of ecosystem services represents an instrumental perspective on ecosystems – it is about the ways in which ecosystems are useful to humans. As noted by Garpe (2008), the concept thus views ecosystems from a utilitarian perspective. As emphasized by TEEB (2010, Figure 1.4), the concept provides a link between what is going on in an ecosystem in terms of its structures, processes and functions and human well-being. Based on the four categories of provisioning, supporting, regulating and cultural ecosystem services suggested by MA (2005) and illustrated in Figure 2.1, Garpe (2008) and SEPA (2009) identified a number of ecosystem services provided by the marine ecosystems of the Baltic Sea and the Skagerrak, see Table 2.1. Definitions of these services are found in Appendix A.

In the discussion of ecosystem services, it has been observed that some of them tend to be input in ecosystems' production of other services. For example, the regulating service of mitigation of eutrophication might be manifested in improved opportunities for recreation, i.e. a cultural service. Ecosystem services are therefore often divided into intermediate and final ecosystem services, see e.g. Fisher et al. (2009). As emphasized by COM (2010), this division is likely to help avoiding a narrow focus on final services when making a full listing of ecosystem services and also avoiding double counting when making a monetary assessment of ecosystem services. As Boyd (2010) puts it:

> *"The distinction between final and intermediate goods and services arises in any economic accounting system. Final goods are not necessarily more important or valuable than intermediate goods. Rather, the distinction arises because of the fundamental accounting identity: count everything, but only count it once."* (p. 8)
>
> *"Consider the issue of double-counting in conventional economic accounts, like GDP. Take cars for example. If we counted both cars and the steel used to make them and then weighted carts and steel by their market prices, we will have double counted the value of the steel. The reason is that the steel's value in car production is embodied in the value of the cars. If a good or service's value adds to*

the value of a good or service subsequently sold in the market, it is an intermediate good. The labor, leather, steel, and human capital required to make the car are intermediate goods. The final good is the car itself." (p. 9)

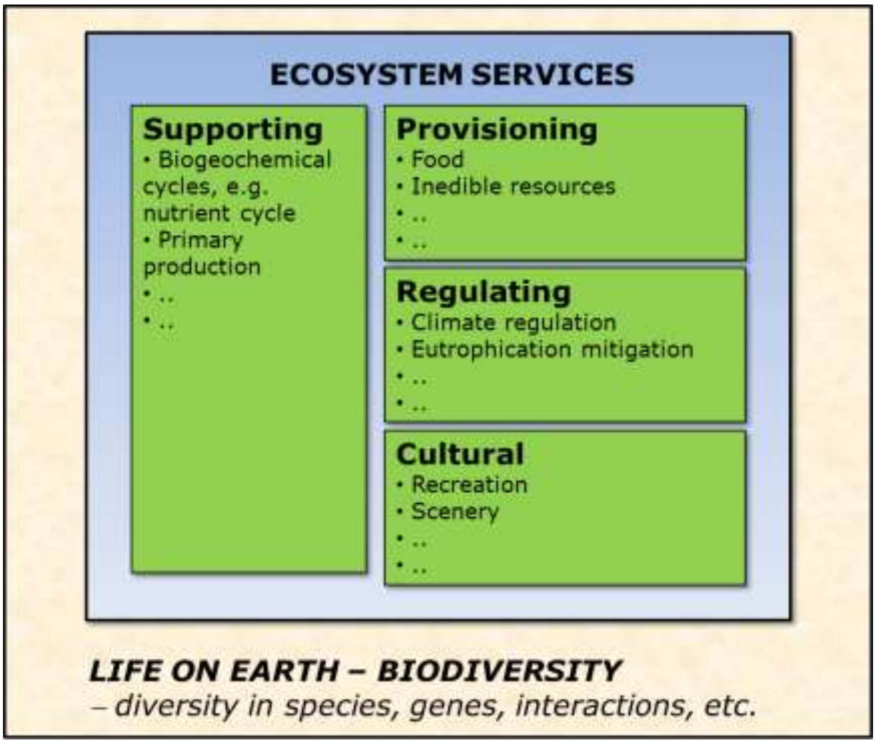

Figure 2.1. Four categories of ecosystem services, after MA (2005).

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C5	Inspiration	Provision of opportunities to inspire art and advertisement.
C6	The legacy of the sea	The appreciation of the marine and coastal environment nature for ethical (non-use) reasons.

To make the services in Table 2.1 operational for an analysis requires that some of them are divided into subcategories. For example, the following seven subcategories of C1 Enjoyment of recreational activities were used in the analysis of marine tourism and recreation in the B report:

C1.1	Swimming
C1.2	Diving
C1.3	Windsurfing, water skiing
C1.4	Boating
C1.5	Fishing
C1.6	Being at the beach or seashore for walking, picnicking, sunbathing, visiting touristic or cultural sites, etc.
C1.7	Using water-based transportation

The C1 subcategories specify which recreational opportunities are supplied by the coastal and marine environment and are based on how people currently use the environment (SEPA, 2010a, 2010b). While such a subcategorization can be useful for a detailed analysis, it is less necessary for this type of synthesis. Therefore, we focus on the main categories in Table 2.1.

2.2 The ecosystem service approach in ESA

The ESA focuses on two components: (1) the use of marine waters and (2) the cost of degradation of the marine environment. COM (2010) describes two different approaches for analysing component (1) – the ecosystem service approach and the marine water accounts approach – and three different approaches for analysing components (2) – the ecosystem service approach, the thematic approach and the cost-based approach.

The Swedish ESA is based on the ecosystem service approach for both components. For the use of marine waters, this approach entails the following steps (COM, 2010, p. 17):

1a. Identifying marine ecosystem services in cooperation with the analysis of status, pressures and impacts;
1b. Identifying and, if possible, quantifying and valuing the well-being derived from the ecosystem services; and
1c. Identifying the drivers and pressures affecting the ecosystem services.

The cost of degradation component requires further refinement of the ecosystem service approach, including a more specific focus on the ecological status and a link to human welfare. It includes the following steps (COM, 2010, p. 35):

2a. Defining good environmental status (GES) using qualitative descriptors, list of elements and list of pressures;
2b. Assessing the environmental status in a business-as-usual (BAU) scenario;
2c. Describing in qualitative and, if possible, quantitative terms the difference between the GES and the environmental status in the BAU scenario. This difference defines the degradation of the marine environment at this point of time; and
2d. Describing the consequences to human well-being of degradation of the marine environment, either qualitatively, quantitatively or in monetary terms. These consequences are the cost of degradation.

The multiple steps involved in each component suggest the important role of the DPSIR framework for sorting out relationships between drivers, pressures, state, impact and response. Figure 2.2 summarizes these terms in the context of the marine environment. *Drivers* are various human activities causing *pressure* on the marine environment through emissions and other types of negative influence. This pressure affects the *state* of marine ecosystems and thus also the supply of intermediate ecosystem services, which in turn creates *impact* on ecosystems' provision of final ecosystem services. As indicated by the dashed arrow in Figure 2.2, this influences those human activities that are dependent on ecosystem services. The impact might also give rise to a *response* in terms of policies to influence the drivers in a way that would reduce their pressures.

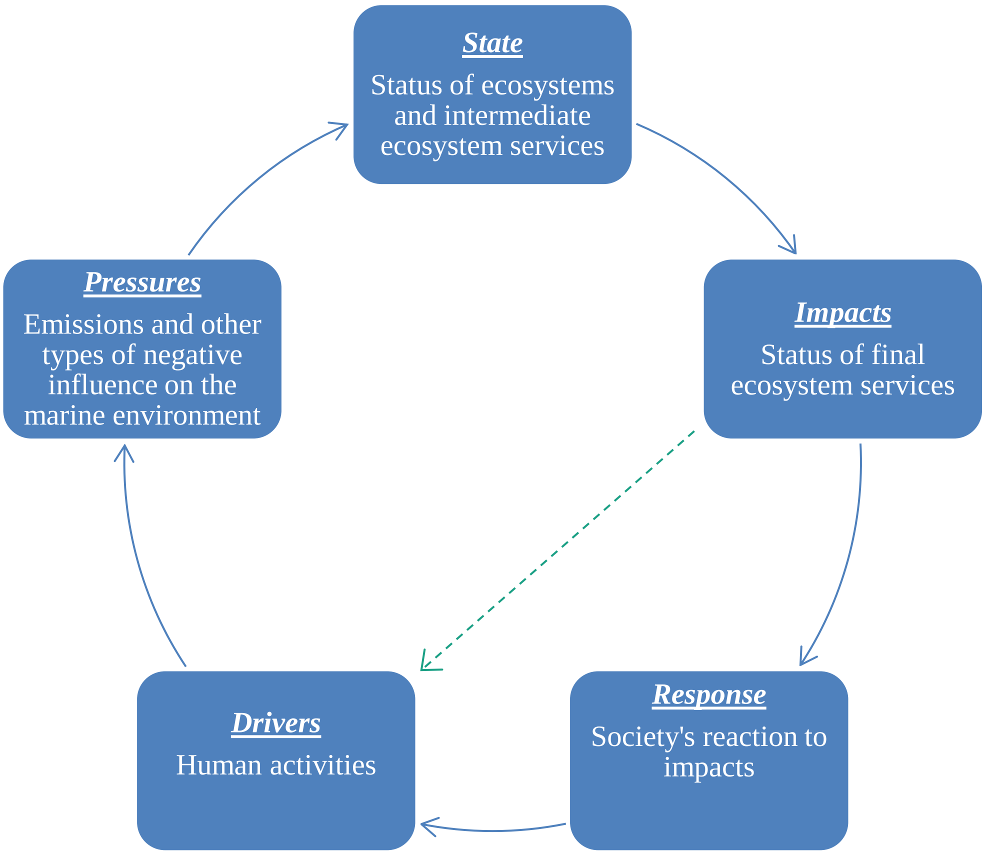

Figure 2.2. The DPSIR framework in an ecosystem service setting.

2.3 Ecosystem service analysis

To inform the ESA ecosystem service approach, we carry out an ecosystem service analysis that in principle follows the procedure of a Corporate Ecosystem Services Review (ESR) as designed by WRI (2008), see also Report B. The purpose of an ESR is to evaluate a company's dependence of and impact on ecosystem services as a basis for identifying the resulting business risks and opportunities. ESR emphasizes the importance of both looking at dependence *and* impact; otherwise the basis for saying something about business risk and opportunities would be incomplete. That is, the goal is to evaluate both how a company influences the status of ecosystem services through its pressure and how the company is affected by the status of ecosystem services. An ESR consists of five steps:

I. Determine the corporate boundaries related to e.g. markets, geographical area, products, customers, etc.
   - In this report, this is done by identifying the human activities (*drivers*) in Chapter 3.

II. Identify the company's impact and dependence on ecosystem services and select those services that are the most important ones in terms of impact and dependence.
   - This is done in Chapter 4 for the human activities by identifying associated pressure on and dependence of ecosystem services and sort out those ecosystem services which are most relevant for an in-depth study.

III. Analyze the status and trends in the selected ecosystem services.
   - This is done in Chapter 5 by associating the selected ecosystem services to GES descriptors and indicators.

IV. Identify business risk and opportunities based on the trends in the selected ecosystem services.
   - This is done in Chapter 6 by analyzing what a business-as-usual scenario says about the trend in GES indicators and implied status of ecosystem services.

V. Develop strategies for minimizing the risks and maximizing opportunities.
   - This last step is rather a part of the future Programmes of Measures than the Initial Assessment of the MSFD.

The usefulness of an ESR hinges upon carrying out different kinds of screenings. Step I is one kind of screening, but the selection in step II is critical as it identifies the most important ecosystem services in terms of impact and dependence. This selection must sort out relatively few ecosystem services to avoid the "cannot-see-the-forest-for-the-trees" problem that may arise with too many dependencies.

In the context of this report screenings are also necessary for the selection of GES descriptors and associated indicators. Since this type of ecosystem service analysis is relatively uncharted territory, it is unavoidable that those screenings and other parts of the work are to a large extent based upon professional judgments.

3 Marine human activities

As mentioned in Chapter 1, the ESA work has entailed four different areas. The first two areas are further subdivided, as in Reports A and B:

A. The maritime sector (driver)
    a. Maritime transport and port activities
    b. Maritime energy sector
    c. Commercial fishing and aquaculture
B. Marine tourism and recreation (driver)
    a. Cruise-ship traffic in marine waters
    b. International passenger ferry traffic in marine waters
    c. National passenger ferry traffic in marine waters
    d. Other commercial passenger transportation in marine waters
    e. Leisure boating in marine waters
    f. Holiday housing associated with marine recreation
    g. Commercial accommodation (e.g. hotels, camping sites, etc.) associated with marine recreation
    h. Same-day visits associated with marine recreation
C. Oil spill (pressure)
D. Marine litter (pressure)

Relating these areas to the DPSIR framework, areas A and B can be identified as human activities constituting drivers and thus the focus of this synthesis. This implies that a number of other drivers causing pressures on the marine environment are excluded from the analysis. Some of the drivers that may be missing are shown in Table 3.1, which lists human activities mentioned by HELCOM (2010a). At least three major gaps can be identified: Agriculture, non-maritime industry and municipal and private generation of wastewater. These three human activities account for substantial pressure in terms of, for example, emissions of nutrients and various hazardous substances. The results of the synthesis must thus be interpreted with this delimitation in mind.

Table 3.1. Main human activities causing pressure on the marine environment. Source: HELCOM (2010a, p. 9)

Human activity	Covered by areas A and B?
Waterborne transports and port activities	Yes
Agriculture	No
Municipal and private generation of wastewater	Only to a minor extent
Tourism along the coasts	Yes
Non-maritime industry	No
Maritime industry incl. dredging	Yes
Fisheries	Yes
Hunting	Only recreational hunting

In Figure 3.1, areas A and B have been included as the drivers subject to study in this synthesis. This also implies that the dependence of these human activities on ecosystem services (i.e., the dashed arrow from impacts to drivers) will be investigated. As to pressures, areas C (oil spill) and D (marine litter) constitute two types of pressures from areas A and B. However, as indicated by Figure 3.1, other pressures caused by areas A and B will also be studied. The fact that some important drivers are not taken into account in this synthesis suggests that this may be an incomplete picture of the total pressure on the marine environment and thus on the supply of marine ecosystem services.

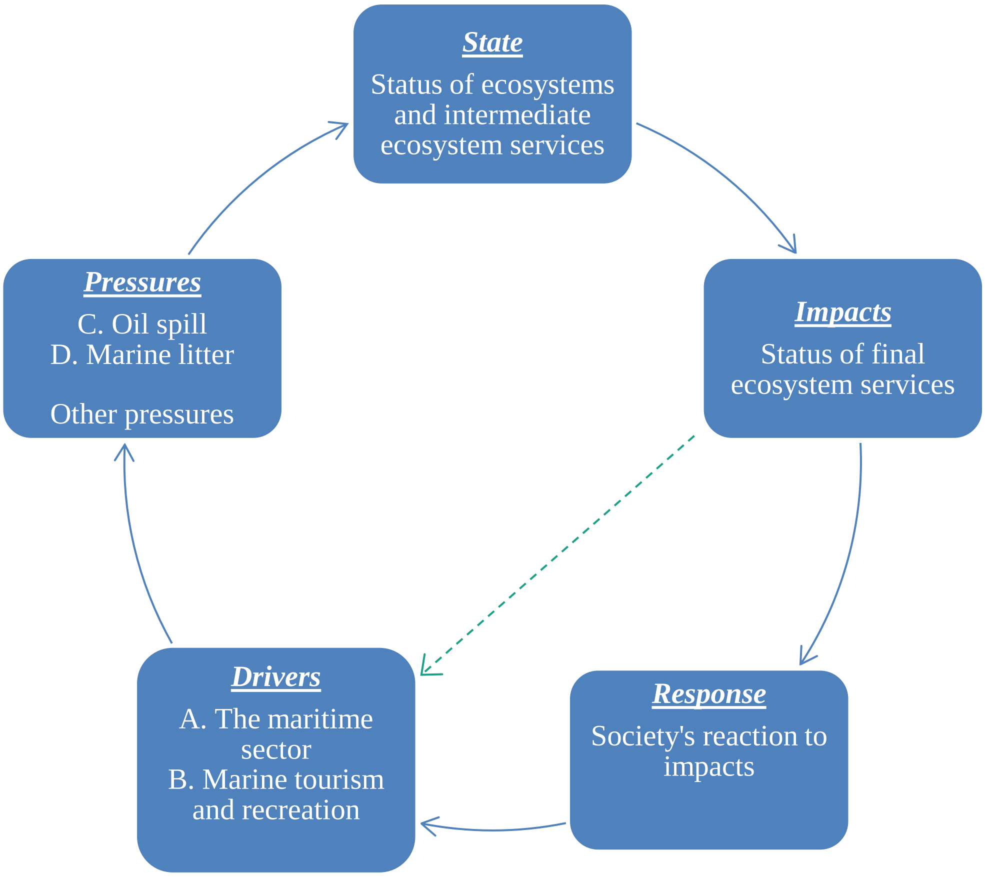

Figure 3.1. Areas A-D in the DPSIR framework.

4 Ecosystem service analysis

Section 4.1 focuses on the dashed arrows in Figure 3.1, i.e. the extent to which the human activities studied in this synthesis are dependent on marine ecosystem services. Conclusions about these dependencies are instrumental for discussions in Chapter 6 about how human activities, and thus human welfare, are likely to be affected by future changes in the supply of marine ecosystem services. The conclusions are also helpful for Section 4.2, where we identify the pressures caused by the human activities studied in this synthesis and what marine ecosystem services are primarily affected by these pressures. This forms the basis for our conclusions in Section 4.2 regarding which marine ecosystem services require further in-depth study in the rest of the report.

4.1 Drivers' dependence on ecosystem services

Based on findings in the ABCD reports, Table 4.1 describes the main dependencies of the human activities studied in this synthesis on marine ecosystem services. In the just mentioned reports, it was found that the supporting services S1-S6 and R1 Climate and atmospheric regulation typically play a fundamental role for the provision of most of the other ecosystem services. S1-S6 and R1 are therefore merged into one column in Table 4.1. The human activities in Table 4.1 are divided into six groups according to how they are dependent on various ecosystem services. The results are summarized below. It should be emphasized that this study focuses on the direct dependencies and therefore excludes some indirect dependencies. For example, human activities in general use the environment to dispose of waste and emissions. While this use is covered in Section 4.2 as a pressure, it should be noted that the effects of such disposal are reduced because of the presence of ecosystem services such as R3 Eutrophication mitigation and R5 Regulation of hazardous substances. In the absence of these services, the pressure would have been more substantial, possibly leading to restrictions against the human activities. However, this report does not further analyze these indirect dependencies on ecosystem services.

1. Maritime transport and port activities (A.a in Chapter 3).
    - Depend only on P7 Space and waterways, which is a final ecosystem service independent of other ecosystem services.

2. Maritime energy sector (A.b in Chapter 3).
    - Dependent primarily on P7 Space and waterways as a final ecosystem service, though the groups S1-S6 and R1 are considered fundamental for providing windy conditions (see Wind power in Report A). Wave power is currently a negligible activity and therefore has no dependence on P6 Energy.

3. Commercial fisheries and aquaculture (A.c in Chapter 3).
    - Dependent on P7 Space and waterways as a final ecosystem service. However, this activity also depends on P1 Food, which in turn requires input of several intermediate services (R3 Eutrophication mitigation, R4 Biological regulation and R5 Regulation of hazardous substances), besides the dependence on the fundamental group S1-S6 and R1.

4. Recreational fisheries (a component in B.e-B.h in Chapter 3).
    - Dependent on various recreational aspects in addition to the dependencies noted above for commercial fisheries and aquaculture. This includes C1 Enjoyment of recreational activities (final service), and the two intermediate services C2 Scenery and C4 Cultural heritage. Further, P1 Food is viewed as an intermediate service for C1 Enjoyment of recreational activities rather than a final service.

5. Marine tourism and recreation focusing on the use of ships/boats (B.a-B.e in Chapter 3).
    - Dependent on P7 Space and waterways (final service) and C1 Enjoyment of recreational activities as a supporting final service. Note that C1 requires input of R3 Eutrophication mitigation, C2 Scenery and C4 Cultural heritage as intermediate services. R3 is included because eutrophication effects have a substantially negative impact on recreational quality.

6. Marine tourism and recreation excluding the use of ships/boats (B.f-B.h in Chapter 3).
    - Dependent on C1 Enjoyment of recreational activities (final service) along with intermediate services R3, C2 and C4. This is further dependent upon R5 Regulation of hazardous substances (intermediate service) because this type of recreation depends on clean water (see Report B).

Table 4.1. Main dependencies of sectors on marine ecosystem services

Sec-tors	Ecosystem services																	
	S1-S6, R1	**R2**	**R3**	**R4**	**R5**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**
	Supp & cli. atm. reg.	**Sed reg**	**Eutr mit**	**Bio reg**	**Reg haz sub**	**Food**	**Ined goods**	**Gen res**	**Che res**	**Orn res**	**Ener-gy**	**Spa-ce & w w**	**Recr**	**Sce-nery**	**Sci & edu**	**Cul her**	**Inspi-ration**	**Le-gacy of sea**
A.a												Final						
A.b	Fu											Final						
A.c	Fu		I for P1	I for P1	I for P1	Final						Final						
Recr. fish.	Fu		I for P1	I for P1	I for P1	I for C1						Final	Final	I for C1		I for C1		
B.a-B.e	Fu		I for C1									Final	Final	I for C1		I for C1		
B.f-B.h	Fu		I for C1		I for C1								Final	I for C1		I for C1		

Fu = fundamental marine ecosystem service
I = intermediate marine ecosystem service
Final = final marine ecosystem service
A.a = maritime transports and port activities
A.b = maritime energy sector
A.c = commercial fisheries and aquaculture
Recr. fish. = recreational fisheries (a component in B.e-B.h)
B.a-B.e = marine tourism and recreation focusing on the use of ships/boats
B.f.-B.h = marine tourism and recreation excluding the use of ships/boats

4.2 Drivers' impact on ecosystem services

We now analyze how the human activities studied in this synthesis influence the supply of ecosystem services. In our analysis we group activities together according to the pressures they cause. The activities in Section 4.1 are therefore regrouped as follows:

- Maritime transport and port activities, including marine tourism and recreation focusing on the use of ships/boats (A.a and B.a-B.e in Chapter 3).
- Maritime energy sector (A.b in Chapter 3).
- Commercial fishing and aquaculture (A.c in Chapter 3).
- Marine tourism and recreation not focusing on the use of ships/boats (B.f-B.h in Chapter 3).

For each of these four human activities, we first identify the main pressures associated with the activities, largely according to the pressure themes as defined in COM (2011). Table 4.2 describes how the pressures in Tables 4.3-4.6 are related to the pressure themes in COM (2011), including the more detailed "sub-pressures". Subsequently, we identify whether the pressures influence the supply of the marine ecosystem services positively (+) and/or negatively (-), based primarily on the findings in the ABCD reports. The results are presented in Tables 4.3-4.6.

Table 4.2. Pressures and sub-pressures covered by the analysis in this report, and their relationship to pressure themes and pressures in COM (2011).

Pressures in this report	**Pressure themes in COM (2011)**	**Pressures in COM (2011), "sub-pressures"**
Physical damage and loss, including physical disturbance	Physical loss	Smothering
		Sealing
	Physical damage	Siltation
		Abration
		Extraction
	Other physical disturbance	Underwater noise
		Marine litter
Hazardous substances and release of substances	Contamination by hazardous substances	Synthetic compounds
		Non-synthetic substances
		Radio-nuclides
	Systematic and/or intentional release of substances	Other substances
Eutrophication	Nutrient and organic matter enrichment	Fertilisers and other nitrogen and phosphorus-rich substances
		Organic matter
Biological disturbance	Biological disturbance	Microbial pathogens
		Non-indigenous species and translocations
		Extraction of species, including non-target catches

Note:

- In this report, oil spills are treated as a separate pressure from maritime transport and port activities because of its detailed analysis in the C report.
- The pressure theme of interference with hydrological processes in COM (2011) is not taken into account in this report because its effects are minor in Swedish marine waters, cf. the A report.

Table 4.3. Main impact on the supply of marine ecosystem services from maritime transport and port activities, including marine tourism and recreation focusing on the use of ships/boats.

Ecosystem service		Pressure				
		Physical damage and loss, including physical disturbance	**Hazardous substances and release of substances**	**Oil spills**	**Eutrophica-tion**	**Biological disturbance**
S1	Biogeochemical cycling					
S2	Primary production				+	
S3	Food web dynamics					
S4	Diversity	-	-	-		
S5	Habitat	-	-	-	-	-
S6	Resilience			-		
R1	Climate and atmospheric regulation				+	
R2	Sediment retention	-	-		-	
R3	Eutrophication mitigation				-	
R4	Biological regulation					
R5	Regulation of hazardous substances	(-)	-		+	
P1	Food		-		-	
P2	Inedible goods				+	
P3	Genetic resources			-		
P4	Chemical resources			-		
P5	Ornamental resources					
P6	Energy					
P7	Space and waterways					
C1	Recreation	-	-	-		
C2	Scenery	-		-		
C3	Science and education					
C4	Cultural heritage					
C5	Inspiration			-		
C6	The legacy of the sea	-		-		

Table 4.4. Main impact on the supply of marine ecosystem services from the maritime energy sector

Ecosystem service		Pressure			
		Physical damage and loss, including physical disturbance	**Hazardous substances and release of substances**	**Eutrophica-tion**	**Biological disturbance**
S1	Biogeochemical cycling				
S2	Primary production				
S3	Food web dynamics				
S4	Diversity	-			
S5	Habitat	-			
S6	Resilience				
R1	Climate and atmospheric regulation				
R2	Sediment retention	-			
R3	Eutrophication mitigation				
R4	Biological regulation				
R5	Regulation of hazardous substances				
P1	Food	(-)			
P2	Inedible goods				
P3	Genetic resources				
P4	Chemical resources				
P5	Ornamental resources				
P6	Energy				
P7	Space and waterways				
C1	Recreation	-			
C2	Scenery	-			
C3	Science and education				
C4	Cultural heritage				
C5	Inspiration				
C6	The legacy of the sea				

Table 4.5. Main impact on the supply of marine ecosystem services from commercial fishing and aquaculture

Ecosystem service		**Pressure**			
		Physical damage and loss, including physical disturbance	**Hazardous substances and release of substances**	**Eutrophica-tion**	**Biological disturbance**
S1	Biogeochemical cycling				
S2	Primary production			+	
S3	Food web dynamics				
S4	Diversity	-			-
S5	Habitat	-		-	
S6	Resilience				
R1	Climate and atmospheric regulation			+	
R2	Sediment retention	-		-	
R3	Eutrophication mitigation			-	
R4	Biological regulation				+
R5	Regulation of hazardous substances		-	+	
P1	Food		-	+ and -	-
P2	Inedible goods			+	-
P3	Genetic resources				-
P4	Chemical resources				
P5	Ornamental resources				
P6	Energy				
P7	Space and waterways				
C1	Recreation	-		-	-
C2	Scenery	-		-	-
C3	Science and education				
C4	Cultural heritage				
C5	Inspiration				
C6	The legacy of the sea	-			

Table 4.6. Main impact on the supply of marine ecosystem services from marine tourism and recreation not focusing on the use of ships/boats.

Ecosystem service		Pressure			
		Physical damage and loss, including physical disturbance	**Hazardous substances and release of substances**	**Eutrophica-tion**	**Biological disturbance**
S1	Biogeochemical cycling				
S2	Primary production			+	
S3	Food web dynamics				
S4	Diversity				
S5	Habitat				
S6	Resilience				
R1	Climate and atmospheric regulation				
R2	Sediment retention				
R3	Eutrophication mitigation			-	
R4	Biological regulation				
R5	Regulation of hazardous substances		-		
P1	Food		-		
P2	Inedible goods				
P3	Genetic resources				
P4	Chemical resources				
P5	Ornamental resources				
P6	Energy				
P7	Space and waterways				
C1	Recreation	-			
C2	Scenery	-			
C3	Science and education				
C4	Cultural heritage				
C5	Inspiration				
C6	The legacy of the sea	-			

The information in Tables 4.3-4.6 is summarized in Table 4.7, which illustrates the main impact of the four types of human activities on the supply of marine ecosystem services. Since there is no information available on the relative strength of the positive and negative impacts in Tables 4.3-4.6, our analysis assigns a "+" ("–") to a particular cell if at least one of the pressures caused by this human activity is found to lead to a positive (negative) impact on the ecosystem service. The assignment of "+ and –" in a cell indicates that the human activity has both a positive and negative impact. In Tables 4.3 and 4.4, the impact from the maritime and energy sectors on R5 Regulation of hazardous substances and P1 Food is marked with brackets to indicate that the effect from physical damage has only a *potential* impact on these ecosystem services, according to Garpe (2008).

The key contribution of this report is to use the information in Table 4.7 to filter out a few ecosystem services that are relevant for an in-depth analysis in the rest of the report. Our approach simply counts the number of + or – signs to indicate services seem to account for the most substantial impact from the human activities. This suggests that C1 Enjoyment of recreational activities and C2 Scenery should be selected because these are the only services that have four minus signs in Table 4.7. We use this as an argument for selecting C2, because C2 has been identified as an intermediate service for C1.

Among the several ecosystem services that have three negative signs in Table 4.7, we select S4 Diversity and R3 Eutrophication mitigation for further analysis. The reason for choosing R3 is primarily the fact that Table 4.1 indicates that R3 plays an important role as an intermediate service on which human activities depend. This is not surprising given that eutrophication effects are a major issue in both the Baltic Sea and the Swedish part of the North Sea. S4 Diversity falls within the fundamental group (i.e., S1-S6 and R1) and is judged to be important because of the basis it gives to most other ecosystem services. Among these services, S4 Diversity plays a key role as an intermediate ecosystem service by contributing to ecosystem productivity and overall functioning of habitats. Further, we consider S4 to be sensitive to pressures from the maritime sector and hence a possible indicator of management and policy success.

To conclude we select S4 Diversity, R3 Eutrophication mitigation and C2 Scenery as those intermediate services that are judged to be relevant for an in-depth study in the rest of this report. The next step in Chapter 5 links GES descriptors and indicators to these three services and then assesses the current status of these services.

Table 4.7. Main impact of human activities on the supply of marine ecosystem services (as screened in the different reports).

Ecosystem services		Maritime transport and port activities, incl. marine tourism and recr. focusing on the use of ships/boats	Maritime energy sector	Fisheries and aquaculture	Marine tourism and recreation not focusing on the use of ships/boats
S1	Biogeochemical cycling				
S2	Primary production	+		+	+
S3	Food web dynamics				
S4	Diversity	-	-	-	
S5	Habitat	-	-	-	
S6	Resilience	-			
R1	Climate and atmospheric regulation	+		+	
R2	Sediment retention	-	-	-	
R3	Eutrophication mitigation	-		-	-
R4	Biological regulation			+	
R5	Regulation of hazardous substances	+ and -		+ and -	-
P1	Food	-	-	+ and -	
P2	Inedible goods	+		+ and -	
P3	Genetic resources	-		-	
P4	Chemical resources	-			
P5	Ornamental resources				
P6	Energy				
P7	Space and waterways				
C1	Recreation	-	-	-	-
C2	Scenery	-	-	-	-
C3	Science and education				
C4	Cultural heritage				
C5	Inspiration	-			
C6	The legacy of the sea	-		-	-

5 Ecosystem services and GES descriptors and indicators

For assessing current status and future trends, we need information on which factors are influencing the availability of the selected intermediate ecosystem services identified above: S4 Diversity, R3 Eutrophication mitigation and C2 Scenery. This chapter explains how we make the link between these services and the GES descriptors and associated indicators defined in COM (2011).

5.1 Linking selected ecosystem services to GES descriptors and indicators

As shown in Table 5.1, we conclude that S4 Diversity is most closely connected to descriptor D1 – *"Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions"*. It is worth noting that the concept of ecosystem services in Figure 2.1 suggests that the four categories of services are surrounded by a larger system of diversity in species, gene and interactions – which is close to the definition of biodiversity (see below).

Further, we find R3 Eutrophication mitigation to be most closely related to descriptor D5 about eutrophication *("human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters")*. Finally, C2 Scenery was found to have a close connection to descriptor D10 about marine litter (*"properties and quantities of marine litter do not cause harm to the coastal and marine environment"*), as well as descriptor D8 about contaminants (*Concentrations of contaminants are at levels not giving rise to pollution effects*). For descriptor D8, one of the indicators reflects the occurrence of significant acute oil pollution events. In general, the descriptors have an ecological focus whereas people's enjoyment of scenery is determined by many subjective factors.

Table 5.1. Linking selected intermediate ecosystem services to GES descriptors.

GES descriptor	**Selected intermediate ecosystem services**		
	S4: Diversity	R3: Eutrophication mitigation	C2: Scenery
D1: Biological diversity	X		
D2: Non-indigenous species			
D3: Population of commercial fish/shell fish			
D4: Elements of marine food webs			
D5: Eutrophication		X	
D6: Sea floor integrity			
D7: Alteration of hydrographical conditions			
D8: Contaminants			X
D9: Contaminants in fish and seafood for human consumption			
D10: Marine litter			X
D11: Introduction of energy, including underwater noise			

We now proceed by going through each of the GES descriptors D1, D5, D8 and D10 for discussing the associated indicators and identifying those which are influencing the status of ecosystem services.

5.1.1 Selection of indicators for D1 Biological diversity

The first step is to determine what indicators are relevant for describing the ecosystem service S4 Diversity with regard to the human activities studied in this synthesis. The GES diversity descriptor D1 includes 14 indicators. Apparently, all indicators describe the status of the ecosystem service, but for practical reasons we find that it is sufficient to concentrate on a subset of these indicators, see Table 5.2. In addition, we do not have sufficient information to evaluate all the listed descriptors. For example, knowledge about the genetic structure of the Baltic Sea ecosystem is at best limited.

Garpe (2008) introduce diversity in terms of an ecosystem function with the following words: *"The benefits of biodiversity to other ecosystem services are numerous. Biodiversity typically enables an ecosystem to perform a variety of functions, thus providing various ecosystem services, while buffering against natural and human-induced disturbance (…). The potential of diversity (particularly functional and genetic) to maintain resilience and support resource extraction may become increasingly critical in the current light of global environmental change."* (p. 49).

Biodiversity concerns the richness in variation among living organisms and their complex ecological relationships, which is vital for the delivery of valuable ecosystem goods and services. Diversity in this respect concerns variation within species, among species and between ecosystems. The status in terms of biodiversity is not only determined by the number of species but needs to be evaluated with respect to the deviation from natural conditions regarding genetic, species and ecosystem diversity. In addition to eutrophication and hazardous substances, biodiversity is currently affected by fisheries, habitat destruction and climatic change (e.g. affecting salinity).

Variation within species is thus one important aspect of biodiversity maintaining the resilience of single species to external pressures. Such variation could potentially be indicated by the genetic structure of species populations. For practical reasons, we assume that population size is a reasonable proxy for genetic variation and hence include indicator 1.2.1 in our evaluation.

Diversity among species indicates that all different species within an ecosystem remain in vital populations. It would also be reflected by distributional range of various species, and for this reason we include indicator 1.1.1 in our analysis.

Diversity between ecosystems requires conservation of different features that characterize an ecosystem in relation to other ecosystems. It thus reflects the extent to which the ecosystem structure of the Baltic Sea and the North East Atlantic is maintained in terms of species composition, productivity, habitat distribution and physical/chemical conditions. Ecosystem structure is described by indicator 1.7 but we find that 1.6.1, 1.6.2 and 1.6.3 in combination with the two previously mentioned indicators are more practical to evaluate and may serve as proxy indicators of maintained ecosystem structure and function.

Table 5.2. Evaluation of indicators for GES descriptor D1.

GES descriptor: D1 Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climatic conditions. **Ecosystem service:** S4 Diversity		
Criterion	**Indicator**	**Evaluation:** What indicators are most relevant for describing the ecosystem service S4 Diversity with regard to the human activities studied in this synthesis?
1.1 Species distribution	1.1.1 Distributional range	X
	1.1.2 Distributional pattern within the latter, where appropriate	
	1.1.3 Area covered by the species (for sessile/benthic species)	
1.2 Population size	1.2.1 Population abundance and/or biomass, as appropriate	X
1.3 Population condition	1.3.1 Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates)	
	1.3.2 Population genetic structure, where appropriate	
1.4 Habitat distribution	1.4.1 Habitat distributional range	
	1.4.2 Habitat distributional pattern	
1.5 Habitat extent	1.5.1 Habitat area	
	1.5.2 Habitat volume, where relevant	
1.6 Habitat condition	1.6.1 Condition of the typical species and communities	X
	1.6.2 Relative abundance and/or biomass, as appropriate	X
	1.6.3 Physical, hydrological and chemical conditions	X
1.7 Ecosystem structure	1.7.1 Composition and relative proportions of ecosystem components (habitats and species)	

5.1.2 Selection of indicators for D5 Eutrophication

The GES eutrophication descriptor D5 includes 8 indicators. Table 5.3 shows which indicators are judged to be relevant for describing the ecosystem service R3 Eutrophication mitigation with regard to the human activities studied in this synthesis. The selection is motivated below and is primarily based on the B report.

An excess discharge of nutrients to the sea is the basis for eutrophication and the indicator for nutrient concentrations (5.1.1) is consequently relevant to consider. The actual nutrient concentration does not necessarily indicate if eutrophication is present or not (e.g. consider high nutrient – low chlorophyll regions). Eutrophication is the accumulation of nutrients in the water. Rather than studying actual nutrient concentrations, it is therefore more interesting to consider the deviation of the nutrient concentration from a “natural” concentration, or to look for trends in the nutrient concentration to determine if nutrients are accumulating or not.

Ratios between nitrogen, phosphorus and silica, indicator 5.1.2, give information about what nutrient is limiting. For example, the nitrogen to phosphorus ratio N/P affects cyanobacteria blooms, which are of relevance to marine recreation.

Eutrophication is often defined as an accumulation of nutrients in the water and an excessive growth of phytoplankton. Chlorophyll concentration, which is easily measured, is used as a proxy for phytoplankton biomass. The indicator chlorophyll concentration is therefore relevant to describe eutrophication. Water transparency is closely related to chlorophyll concentration and hence relevant to consider when dealing with eutrophication.

Indicator 5.2.4, shift in floristic composition, includes bloom events of nuisance/toxic algal blooms. For marine recreation activities close or in the water, algal blooms are a big nuisance. For this indicator only algal blooms are considered.

Abundance of perennial seaweeds and seagrasses adversely impacted by decrease in water transparency, indicator 5.3.1, is closely related to chlorophyll concentration in the water and to nutrient concentrations.

Dissolved oxygen is also marked as a relevant indicator. When biomass decays oxygen is consumed and low oxygen levels or hypoxia occurs. Just as for nutrient levels, the oxygen level needs to be considered relative to natural or undisturbed conditions as there are areas that are naturally low in oxygen.

The objective of this study is not to analyse eutrophication and all of its indicators but rather to use a few of them to determine the status and trend of the ecosystem service with regard to the relevant maritime activities. We will therefore concentrate on nutrient levels (5.1.1), the reason that eutrophication occurs, and on toxic algal blooms (included in 5.2.4), which are the most obvious way that eutrophication affects marine recreation.

Table 5.3. Evaluation of indicators for GES descriptor D5.

GES descriptor: D5 Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters. **Ecosystem service:** R3 Eutrophication mitigation		
Criterion	**Indicator**	**Evaluation:** What indicators are most relevant for describing the ecosystem service R3 Eutrophication mitigation with regard to the human activities studied in this synthesis?
5.1 Nutrients level	5.1.1 Nutrients concentration in the water column	X
	5.1.2 Nutrient ratios (silica, nitrogen and phosphorus), where appropriate	
5.2 Direct effects of nutrient enrichment	5.2.1 Chlorophyll concentration in the water column	
	5.2.2 Water transparency related to increase in suspended algae, where relevant	
	5.2.3 Abundance of opportunistic macroalgae	
	5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities	X
5.3 Indirect effects of nutrient enrichment	5.3.1 Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency	
	5.3.2 Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned	

5.1.3 Selection of indicators for D8 Contaminants

The GES descriptor D8 includes 3 indicators. Table 5.4 shows which indicators are judged to be relevant for describing the ecosystem service C2 Scenery with regard to oil spills. The selection is motivated below and is primarily based on the C report.

Oil spills give rise to several environmental impacts – one of them being a distinct impact to the coastal scenery in the affected area for a period of time. Indicator 8.2.2 in Table 5.4 captures this impact, whereas indicators 8.1.1 and 8.2.1 rather describe non-visible effects from oil spills. Changes in the latter two indicators, however, might in the long run perhaps lead to visible impacts, but we judge indicator 8.2.2 to be the most relevant indicator for describing impacts to the coastal scenery. Further, indicator 8.2.2 might also be a good starting point for describing also expected impacts to other ecosystem services from oil spills – if there is no occurrence of significant acute oil spills, it will be reflected in this indicator. If there are many significant acute oil spills, it will perhaps be reflected in this indicator first.

Table 5.4. Evaluation of indicators for GES descriptor D8.

GES descriptor: D8 (Concentrations of contaminants are at levels not giving rise to pollution effects.) **Ecosystem service:** C2 Scenery		
Criterion	**Indicator**	**Evaluation:** What indicators are most relevant for describing the ecosystem service C2 Scenery with regard to the human activities studied in this synthesis?
8.1 Concentration of contaminants	8.1.1 Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with assessments under Directive 2000/60/EC	
8.2 Effects of contaminants	8.2.1 Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored	
	8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution	X

5.1.4 Selection of indicators for D10 Marine litter

The GES descriptor D10 deals with marine litter. Here we select the indicators that are relevant for the ecosystem service C2 Scenery in terms of the relevant maritime activities, see Table 5.5. The selection of indicators is therefore primarily determined by the visual aspect of marine litter, and based on the analysis in the B report. The indicators that capture the visual aspect are indicators 10.1.1, marine litter washed ashore or deposited on the coastlines, and 10.1.2, amount of litter in the water column or deposited on the sea floor. Most of the marine recreation activities take place at the coast and we therefore choose to focus the further analysis on the indicator for marine litter on land, i.e. 10.1.1. Neither of the indicators 10.1.3 (micro-particles in the water) and 10.2.1 (litter ingested by marine mammals) are judged to have a direct effect on how scenery is experienced.

Table 5.5. Evaluation of indicators for GES descriptor D10.

GES descriptor: D10 (Properties and quantities of marine litter do not cause harm to the coastal and marine environment.) **Ecosystem service:** C2 Scenery		
Criterion	**Indicator**	**Evaluation:** What indicators are most relevant for describing the ecosystem service C2 Scenery with regard to the human activities studied in this synthesis?
10.1 Characteristics of litter in the marine and coastal environment	10.1.1 Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source	X
	10.1.2 Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source	
	10.1.3 Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics)	
10.2 Impacts of marine litter on marine life	10.2.1 Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis)	

5.1.5 Selection of indicators: Summary

The selection above of those indicators which are judged to primarily influence the status of the ecosystem services is summarized by Table 5.6.

Table 5.6. List of selected indicators influencing the status of the ecosystem services.

GES descriptor	Ecosystem service	Selected indicator
D1	S4 Diversity	1.1.1 Distributional range
		1.2.1 Population abundance and/or biomass, as appropriate
		1.6.1 Condition of the typical species and communities
		1.6.2 Relative abundance and/or biomass, as appropriate
		1.6.3 Physical, hydrological and chemical conditions
D5	R3 Eutrophication mitigation	5.1.1 Nutrients concentration in the water column
		5.2.4 Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities
D8	C2 Scenery	8.2.2 Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution
D10	C2 Scenery	10.1.1 Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source

5.2 Current status of selected indicators and ecosystem services

Below we first describe the current status of the indicators listed in Table 5.6, i.e. those which were judged to primarily affect the selected ecosystem services. We also discuss what this status implies for the selected ecosystem services.

5.2.1 D1 Biological diversity

For this descriptor five indicators were selected:

- 1.1.1 Distributional range (species)
- 1.2.1 Population abundance and/or biomass (population)
- 1.6.1 Condition of the typical species and communities (habitat)
- 1.6.2 Relative abundance and/or biomass (habitat)
- 1.6.3 Physical, hydrological and chemical conditions (habitat)

5.2.1.1 1.1.1 DISTRIBUTIONAL RANGE (SPECIES)

The status of this indicator depends on the extent to which native species inhabit a certain ecosystem. In the brackish waters of the Baltic Sea a relatively small number of keystone species make up the food web skeleton, compared with the much greater variability between species in the North East Atlantic region (Elmgren, 1984). This makes the Baltic Sea ecosystem more vulnerable to pressures, reinforced by the fact that many species occur at their biophysical limit in terms of salinity. One of the keystone species having a fundamental role in the ecosystem – the Baltic cod –is genetically unique and the population can thus only be sustained by local recruitment (Garpe, 2008).

The distributional range of various organisms is largely determined by the habitat distributional range (*e.g.* reflected by indicators 1.6.1, 1.6.2 and 1.6.3). One example is the occurrence of eelgrass meadows which is decreasing in the Baltic Sea and along the West Coast of Sweden due to eutrophication (Baden et al., 2003). The extent to which eelgrass habitats are provided by the growth of eelgrass (*Zostera marina*) influences the distributional range of many other species, including younger stages of cod and other fish feeding in these meadows.

The distributional ranges of native species may also be influenced by non-indigenous species. An example is provided by the round goby (*Neogobius melanostomus*) which has invaded the Polish coast and apparently outcompetes and even excludes many native species (Garpe, 2008). Several non-indigenous species now occurring regularly in Swedish marine waters are believed to be introduced by ship ballast waters (including the round goby, the American comb jelly, the red algae *Gracilaria vermiculophylla* and Pacific oyster). The hard surfaces of cables and pipelines may provide opportunities for non-indigenous species to locate.

5.2.1.2 1.2.1 POPULATION ABUNDANCE AND/OR BIOMASS (POPULATION)

This indicator reflects population trends for species inhabiting marine environment, and is also expected to partly reflect genetic variability to the extent that variability correlates with abundance.

In the Baltic Sea and the North East Atlantic, the abundance of many species is negatively affected by human activities. For other species, population trends are positive. There are currently 216 marine species present on the Swedish red list, excluding birds (Garpe, 2008). According to HELCOM (2010a) 59 species are threatened or declining in various parts of the Baltic Sea and many essential coastal habitats are also threatened. At the same time, reduced levels of several hazardous substances and bans on hunting have improved the situation for species like the white-tailed eagle and the grey seal since the 1980s (HELCOM, 2010a). OSPAR (2010) lists 29 species as threatened and/or declining in the North East Atlantic, including invertebrates, birds, fish, reptiles and mammals.

In the marine waters considered in this report, over-fishing is one of the greatest threats to biodiversity. Excessive fishing has reduced the biomass of several fish species, and has also apparently reduced the genetic diversity among Baltic cod (Johannesson et al., 2007). The population of harbour porpoise is affected by involuntary catches by fishing gear. According to Garpe (2008) there is a documented decrease in biodiversity resulting from excessive exploitation and bycatches in the Baltic Sea and Skagerrak. By excessive removal of fish from the system, fisheries also has direct impacts on other ecosystem services including primary production (S2), food web dynamics (S3), habitat (S5) and resilience (S6).

Hazardous substances relating to maritime transports also affect the marine biodiversity. Negative effects from anti-fouling products have been found for many species and aspects including genetic diversity of copepods, decline in germination frequency of macroalgae, imposex or intersex in gastropod species, increased mortality and reduced growth rate in blue mussel larvae. Toxic substances from anti-fouling have also been found in liver tissue of marine mammals in the Baltic Sea and in marine food for human consumption. Key species in the Baltic Sea such as bladder wrack has been shown to be negatively affected by copper and irgarol at very low concentrations. Tributyltin (TBT) has been of widespread use historically but has been banned for all boats since 2008, but high levels of TBT are still found in harbours and marinas. For further details, see Report A.

Effects of non-indigenous species described for indicator 1.1.1 above are also relevant for indicator 1.2.1.

5.2.1.3 1.6.1 CONDITION OF THE TYPICAL SPECIES AND COMMUNITIES (HABITAT)

Examples of pressures on the conditions of the typical species and communities in marine habitats are bottom trawling (abrasion), eutrophication and oil spills.

Hopkins (2003) estimates that 5 000-15 000 km^2 of seafloor is trawled per year in the most intensively trawled 60×60 km rectangles of the Baltic Sea. This means that the seafloor in these regions is trawled 1-4 times per year. Floderus and Pihl (1990) estimate that the sweep and the bottom rope of a trawl penetrates 5-10 cm into the sediment which is thereby resuspended. Nilsson and Rosenberg (2003) report penetration depths in the same range. Physical damage from construction and development also has a documented decrease on marine biodiversity according to Garpe (2008), both due to direct loss of habitat but also deterioration due to increased sedimentation caused by dredging.

Abundance and species composition of the algal community in the water column as an effect of eutrophication in turn affects the marine habitat of other species. Negative impacts of oil spills on key species and communities also affect overall biodiversity.

5.2.1.4 1.6.2 RELATIVE ABUNDANCE AND/OR BIOMASS (HABITAT)

Marine eutrophication is believed to play an important and negative role for the loss of eelgrass meadows along the Swedish coast. The loss of eelgrass meadows along the Swedish west coast is however also believed to be the result of heavy overfishing (top down effects; Pihl et al., 2006) which also affects the service sediment retention (R2).

Loss of habitat is also highly relevant as an effect of bottom trawling, as described for indicator 1.6.1. Urban development (construction of piers, harbours, infrastructure and dredging operations) in the coastal environment of both the Baltic Sea and the North Sea has a negative impact on the maintenance of habitats.

OSPAR (2010) lists 10 threatened and/or declining habitats including coastal, shelf-sea and deep-sea habitats.

5.2.1.5 1.6.3 PHYSICAL, HYDROLOGICAL AND CHEMICAL CONDITIONS (HABITAT)

Oil spills, climate change (both including temperature increase and acidification due to CO_2 accumulation) and eutrophication may potentially decrease marine biodiversity according to Garpe (2008).

Ocean acidification is a phenomenon that causes problems for a range of marine organisms with calcareous shell and would affect marine mollusks, echinoderms and crustaceans at both the individual level and at population level. Effects of acidification due to anthropogenic CO_2 release may become apparent sooner than those of temperature changes.

The nutrient status is obviously a crucial determinant of the biological productivity, and biodiversity is greatly affected by this parameter. As a symptom of eutrophication, oxygen depletion in deep waters and dead bottoms due to anoxia severely impacts marine habitats (Conley et al., 2011).

Non-indigenous species may also influence habitats, including physical conditions. One example includes the introduction of the invading polychaete *Marenzelleria neglecta*, which is likely to have positively contributed to the recovery from hypoxia in parts of the inner Stockholm archipelago and elsewhere in the Baltic Sea (Karlsson et al., 2010; Norkko et al., 2011).

5.2.1.6 STATUS OF ECOSYSTEM SERVICE S4 DIVERSITY

Based on the observation that there is an alarmingly rapid loss of biodiversity, Garpe (2008, p. 50) assess the present status of S4 Diversity to be “moderate”, but that the level of threat is “high”. In addition, several marine species of high importance for the ecosystems are threatened and the effects of their existence in the ecosystems are not yet fully investigated. We therefore conclude that the status of S4 is best described as *insufficient* for both the Baltic Sea and the North Sea.

5.2.2 D5 Eutrophication

For this descriptor the following two indicators are selected. The analysis below follows the B report.

- 5.1.1 Nutrient concentration in the water column
- 5.2.4 Bloom events of nuisance/toxic algal blooms caused by human activities

5.2.2.1 5.1.1 NUTRIENT LEVELS

For the nutrient concentration indicator 5.1.1 there is a large amount of data along the coast of Sweden. Much of this data has already been analysed in terms of eutrophication. On the webpage for the “Vatten InformationsSystem Sverige” (VISS, Water Information Service for Sweden) run by the Länsstyrelsen (County Administrative Board), maps are available showing the status of nutrients levels with regard to eutrophication, as well as the ecological status along the coast of Sweden, and areas where eutrophication is considered to be an environmental problem. Figure 5.1 shows a map of the coastal regions where eutrophication is an environmental issue.

According to Figure 5.1, eutrophication is mainly an issue in southern Sweden along the coast of Skagerrak, Kattegat, and the Baltic Proper. Along the coast in the Gulf of Bothnia there are just a few spots where eutrophication is a problem. In terms of the ecosystem service R3 Eutrophication mitigation, the maps can be interpreted as showing the areas where the ecosystem service is under pressure and where marine recreation may be affected by eutrophication. Figure 5.2 shows the status of nutrient levels with regard to eutrophication.

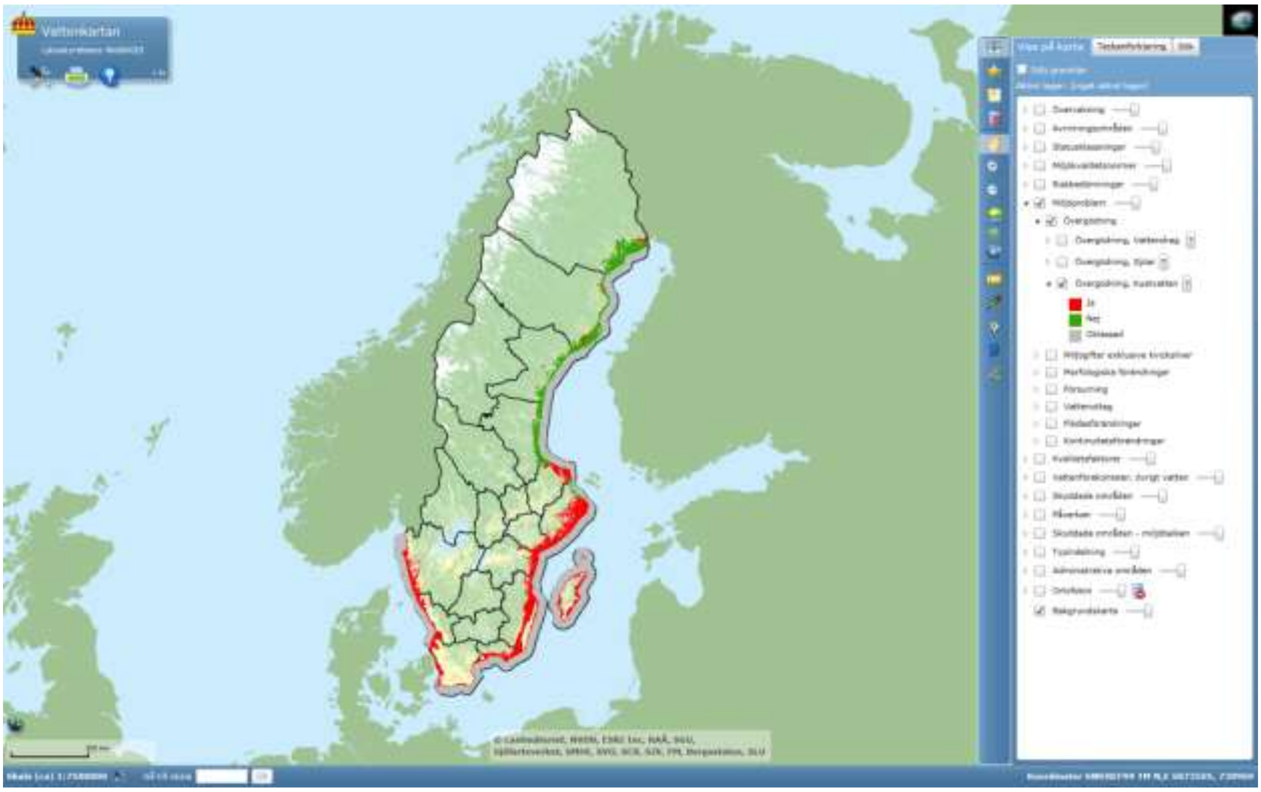

Figure 5.1. Map showing where eutrophication is a problem (red areas). Green areas indicate no problem with eutrophication. Source: VISS (2011).

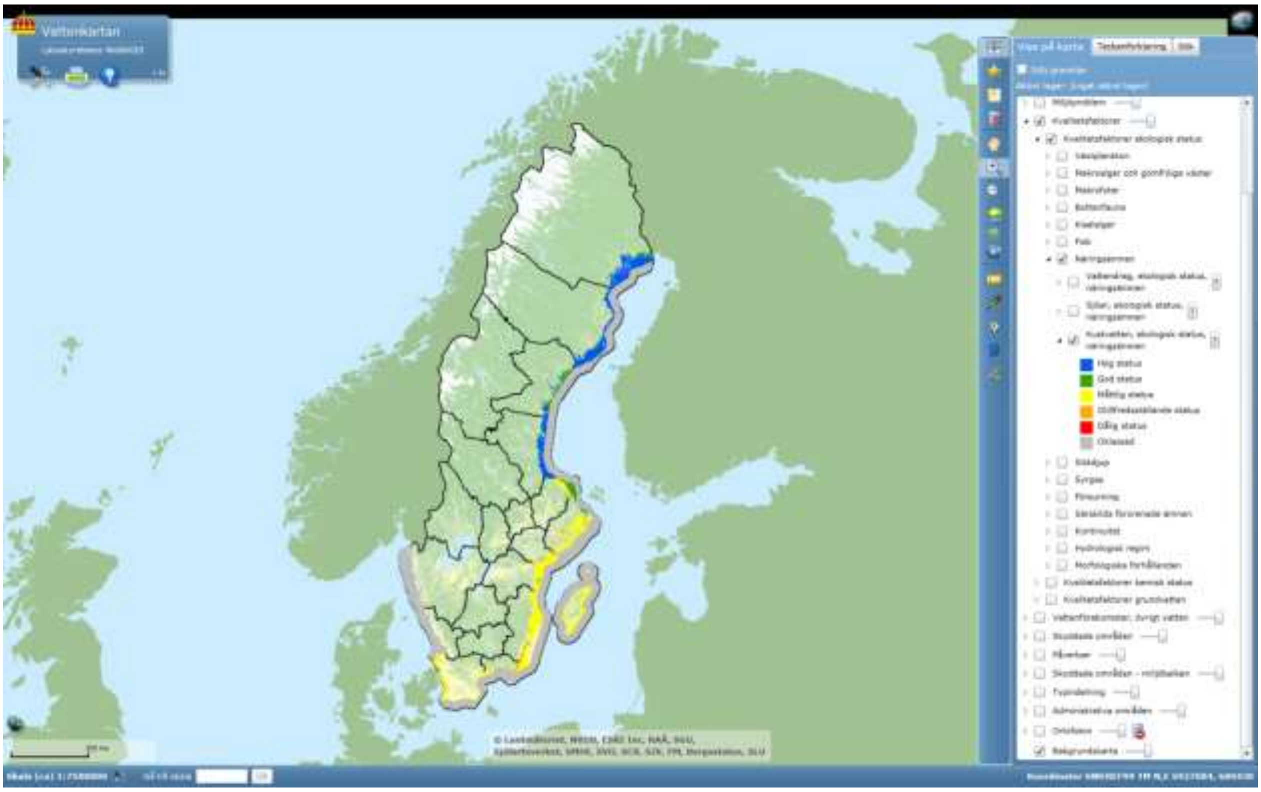

Figure 5.2. Map of status of nutrient levels with regard to ecological status. Blue = High, Green = Good, Yellow = Moderate, Orange = Poor, and Red = Bad. Source: VISS (2011).

5.2.2.2 5.2.4 TOXIC ALGAL BLOOMS

Toxic algal blooms are often measured in terms of amount of cyanobacteria accumulated at the sea surface. There is plenty of large-scale information about cyanobacteria blooms at sea as they can be observed from space. Figure 5.3 shows the number of days that cyanobacteria were observed during the period 1997-2009 and Figure 5.4 for the period 2010-2011. The images show that cyanobacteria mostly occur in the Baltic Sea, and only occasionally in the Gulf of Bothnia. Furthermore, the variation from year to year is large. Compare the year of 2005 when cyanobacteria were observed for 20 days in most parts of the Baltic Sea, with 2007 when cyanobacteria were observed for much shorter periods.

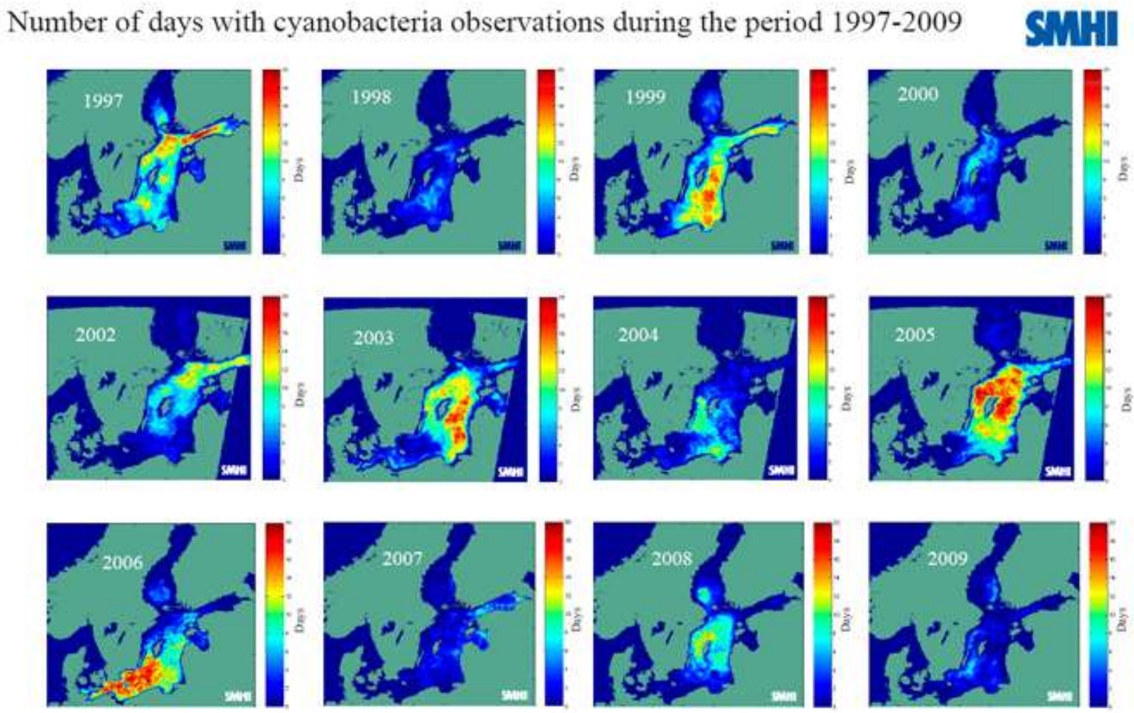

Figure 5.3. Number of days with cyanobacteria observations during the period 1997-2009. Red is 20 days, yellow 13 days and light blue 8 days. Source: HELCOM (2011).

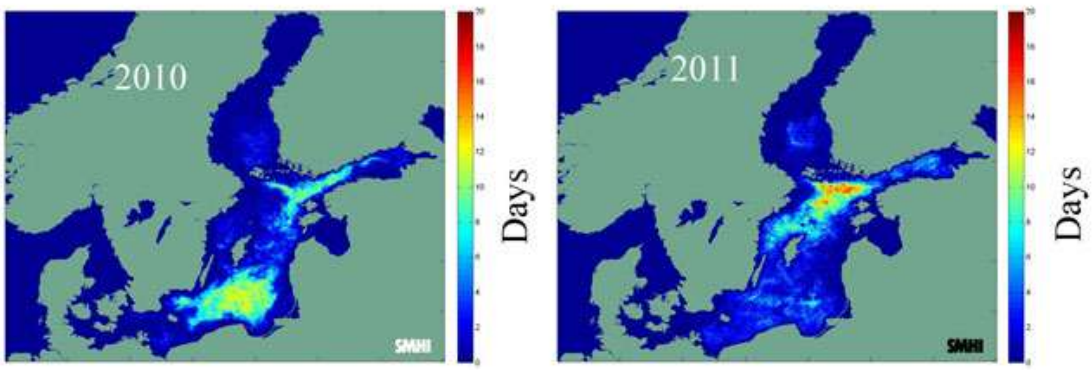

Figure 5.4. Number of days with cyanobacteria observations during the period 2010-2011. Red is 20 days, yellow 13 days and light blue 8 days. Source: HELCOM (2011).

For the case of marine recreation it would be even more relevant to assess the status of algal blooms that affect beaches. This cannot be accomplished with satellites as they have difficulties distinguishing between an algal bloom and vegetation on land. There is a lack of data providing a general picture of on how algal blooms have actually affected beaches.

5.2.2.3 STATUS OF ECOSYSTEM SERVICE R3 EUTROPHICATION MITIGATION

Garpe (2008, p. 80) assessed the status of natural eutrophication mitigation to be “good” in the Baltic Sea and the Skagerrak with the arguments that human use does not influence the provision of R3 and that the organisms responsible for taking care of excess nutrients are not threatened at present. However, the presence of substantial problems from eutrophication effects (cf. Figure 5.1) suggests that the marine ecosystems do not have a sufficient capacity of processing and removing nutrients to an extent that is enough for society. For example, the status of R3 would probably be much better if the stocks of top predators in the marine food web, e.g. cod, could be restored to considerably higher levels. For example, Österblom et al. (2007) presents indications that a clupeid-dominated Baltic Sea because of excessive loads of nutrients and overfishing of cod might exacerbate eutrophication. We therefore conclude that the marine ecosystems are at present not supplying enough eutrophication mitigation for causing a non-disturbing presence of eutrophication effects. As a consequence, the status of R3 is assessed as *insufficient* for both the Baltic Sea (except for the Gulf of Bothnia) and the North Sea.

5.2.3 D8 Contaminants

5.2.3.1 8.2.2 OCCURRENCE, ORIGIN, EXTENT OF SIGNIFICANT ACUTE POLLUTION EVENTS

For the contaminants descriptor D8, indicator 8.2.2 (Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution) was selected. This indicator broadly reflects the amount of significant oil spills.

The C report presented an overview of the risk for oil spills in the Baltic Sea and Northeast Atlantic. The Baltic Sea region is one of the busiest seas in the world, regarding cargo transportation. Today, the Baltic Sea region accounts for up to 15 % of the world’s cargo. Since ships have oil in their fuel tanks, both tankers and non-tankers constitute a source of risk for oil spills. The density of shipping is illustrated in Figure 5.5 with the busiest routes highlighted in yellow. Besides ship traffic in Swedish ports, a number of ships pass through the Swedish EEZ en route to other destinations (e.g., the route east of Gotland).

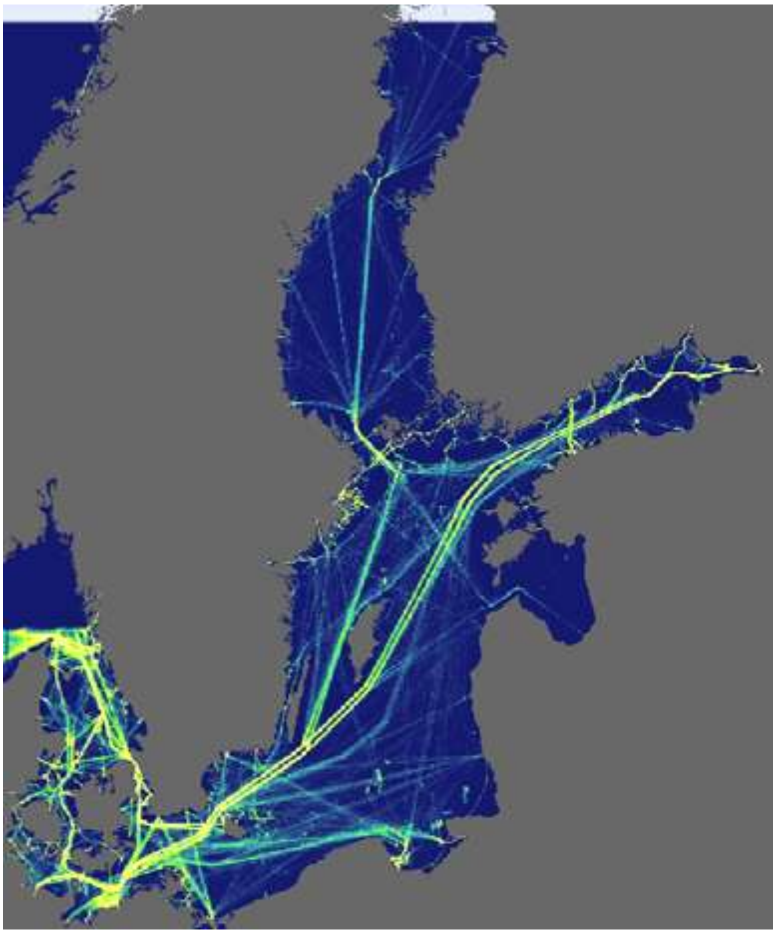

Figure 5.5. The density of ship traffic during one week in 2008, with the busiest routes in the BSR highlighted in yellow (HELCOM, 2009).

There are about 120 shipping accidents per year in the Baltic Sea region. HELCOM (2010b) has analyzed the different types of accidents in the Baltic between 2000 and 2010 and found that 7 % of all accidents resulted in pollution. Groundings and collisions are the most common reasons for accidents (HELCOM, 2010b). Figure 5.6 presents an overview of the reasons for past accidents.

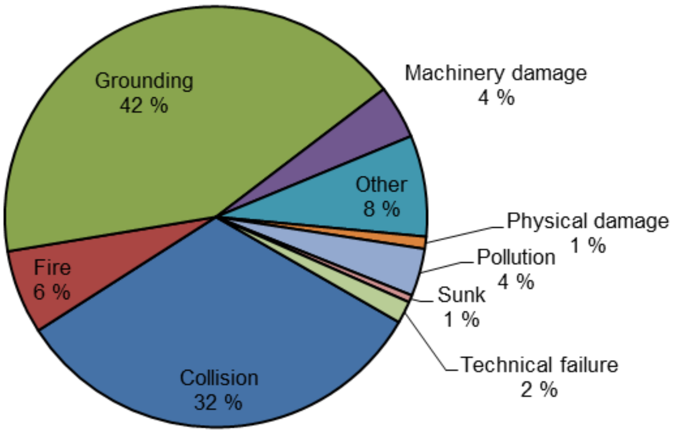

Figure 5.6. Types of accidents in the Baltic Sea during the period 2001-2010. Number of accidents 2001-2010 was 1068. (HELCOM, 2010b)

Today's probability of large (300 – 5000 tons) and exceptional (5000 – 150 000 tons) oil spills in the Baltic Sea is estimated to one every four years, and one every 26 years, respectively (BRISK, 2011).

The status of the ecosystem service C2 Scenery is reviewed in Section 5.2.4.2.

5.2.4 D10 Marine litter

For the marine litter descriptor D10, indicator 10.1.1 (litter washed ashore or found along the coast) was selected. The analysis below follows the B and D reports.

5.2.4.1 10.1.1 LITTER WASHED ASHORE OR FOUND ALONG THE COAST

Since the early 1990's marine litter has been collected and measured at six beaches on the Swedish west coast. The amount of litter found is shown in Table 5.7. In addition to the volume the number of day labours, bags of litter, fish boxes and oil containers found are also shown. The reason for the high volume (15 500 m^3) value in 1992 is that this was the first year the litter was collected and large amounts had accumulated. The relative low numbers in 1996, a total volume of 4000 m^3, is partly a result of extensive ice coverage during the winter season as well as long periods with easterly winds which transported the litter off-shore (Olin, 2010).

Table 5.7. Amount and composition of litter collected in the province of Bohus 1992-2006 (Olin, 2010). Also the number of day labours involved in collecting the litter is shown.

Year	Volume (m^3)	Day labour (number of)	Bags of litter (number of)	Fish boxes (number of)	Oil containers (number of)
1992	15 500	25 000	89 200	2 410	
1993	5 500	6 000	36 071	1 412	2 500
1994	6 000	7 163	36 210	1 231	733
1995	6 000	6 508	34 427	1 229	589
1996	4 000	5 840	22 607	575	1 316
1997	6 000	7 885	36 206	2 020	2 292
1998	6 000	6 480	35 825	1 620	2 290
1999	8 000	7 023	39 103	1 899	2 673
2000	7 000	8 081	48 581	3 046	4 021
2001	5 000	6 214	34 066	1 361	2 393
2002	4 000	5 880	30 119	2 186	2 937
2003	3 000	5 364	24 335	1 631	2 150
2004	3 000	5 472	24 620	1 453	2 099
2005	3 000	4 964	24 131	1 640	2 114
2006	3 000	4 156	19 944	1 072	1 553

Table 5.8. Marine litter found in Sotenäs on the Bohus Coast (D report).

Year	Volume (m^3)	Mass (tons)	Percentage of beaches cleaned
2007	199	19.4	25
2008	152	14.4	25
2009	364	31.9	50
2010	455	42.1	53

The local authorities in Sotenäs on the Bohus Coast have collected marine litter from beaches from 2007 to 2010, see Table 5.8. The collection is carried out between March and October each year. Among the items found are fish boxes, oil containers, medical waste, and refrigerators. The percentage of beaches cleaned is also reported. In 2007 and 2008, marine litter was collected on only 25 % of the beaches while between 2009 and 2010 about half the beaches where cleaned. This shows that marine litter data based on beach clean-up efforts can underestimate the total amount of litter on a beach.

OSPAR collects data at a number of reference beaches along the coastal zones of Europe. Six beaches from the Bohus Coast are included in the OSPAR North Sea programme. Figure 5.7 illustrates the amount of litter in different OSPAR regions and shows that the North Sea is one of the areas most affected by marine litter.

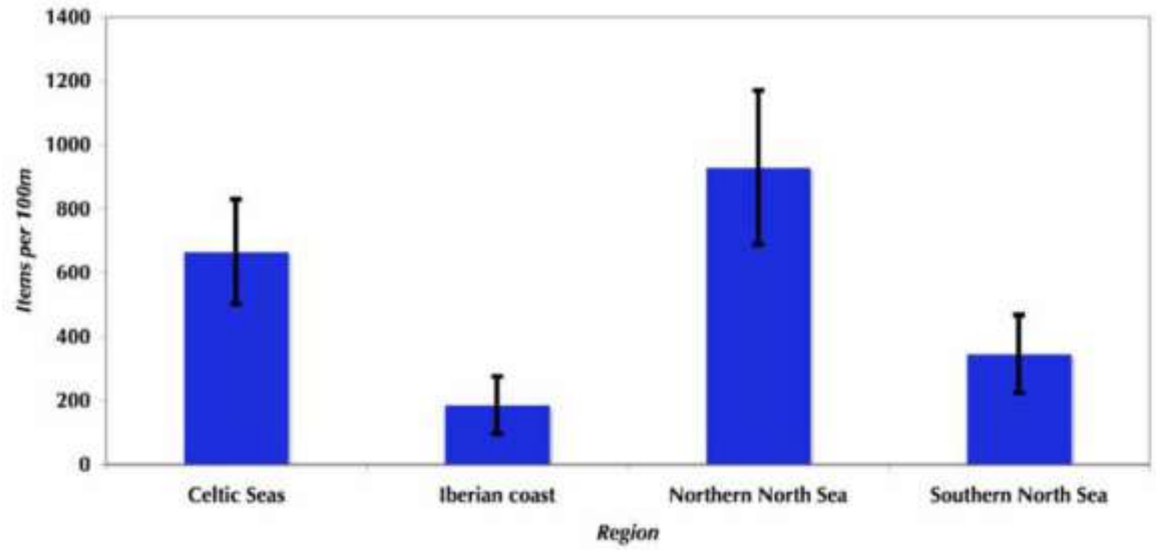

Figure 5.7. Average number of litter items per 100 meters on the reference beaches in the OSPAR regions. (Figure from OSPAR, 2009, p. 5)

For the Swedish east coast in the Baltic Sea, marine litter data is very scarce. When it comes to marine litter, the Swedish east coast receives little attention compared to the west coast, in particular the Bohus Coast. Therefore, in order to estimate the amount of litter on the Swedish Baltic Sea coast, data are used from elsewhere in the Baltic Sea.

Municipalities and NGOs (e.g. WWF and the Ocean Conservancy) gather information about the amount of litter found at beaches in the Baltic Sea. UNEP and the Ocean Conservancy collect information from beach clean-up efforts in the Baltic Sea. Although UNEP (2009) does not include data specific for Sweden we will use it to illustrate typical values for the Baltic Sea. The highest concentration of marine litter found on beaches in the Baltic Sea is 700 to 1200 items per 100 m coastline. These values are very similar to those reported by OSPAR (2009) for the northern North Sea. More typical values for the Baltic Sea are 6 to 16 pieces of litter per 100 m coastline. From these figures we conclude that marine litter on beaches is a larger issue in the North Sea than in the Baltic Sea. However, it is important to keep in mind that local variations can be substantial. Close to the source of the litter (e.g. at a public beach) the amount of litter may be higher, making marine litter to a conspicuous issue.

5.2.4.2 STATUS OF ECOSYSTEM SERVICE C2 SCENERY

The provision of C2 Scenery implies aesthetic values to humans and includes beauty as well as silence, which is appreciated by tourists as well as residents and owners of holiday houses. Clear water, richness of animal and plant species, a feeling of pureness and silence are some important attributes. Besides marine litter and eutrophication effects such as algal mats and cyanobacterial blooms, offshore wind parks, beach erosion, oil spills and decrease in valuable species are examples of phenomena that are likely to have adverse effects on scenery. Garpe (2008, p. 145) assesses the overall status of C2 as “moderate” since substantial development is taking place in many coastal regions. However, there are also great regional differences. Taking into account Garpe’s view and the review of the extent of marine litter above, we assess the status of C2 as *locally insufficient* in both the Baltic Sea and the North Sea. Regarding oil spills, there is also a temporal aspect, since the adverse effect to the scenery from an oil spill can be expected to disappear once the oil has been removed and/or naturally diluted and decomposed.

6 BAU scenario for 2020 and 2050

Section 6.1 discusses the policy responses aimed at the drivers and pressures identified above. While detailed information on these policies are found in the ABCD reports, this section provides a 'high-elevation' perspective of how the policy response has heretofore addressed drivers and pressures, which allows for course identification of overlapping regulations and gaps in coverage. We also provide a crude analysis of policy effectiveness for each driver/pressure with an eye toward improved policy response in the future. Section 6.2 complements the policy effectiveness discussion by considering the anticipated future changes in the drivers and pressures themselves. Section 6.3 contains an analysis of what these future changes imply for selected GES indicators and ecosystem services. Section 6.4 provides some information needs and implications for Sweden's future cost of degradation (COD), and it also assesses the difference between a BAU policy response and the required response to achieve GES.

6.1 Review of existing policies and policy instruments

6.1.1 Overview of driving forces and policy responses

Tables 6.1 and 6.2 provide an overview of the driving forces that have led to subsequent policy responses in a BAU scenario. Table 6.1 focuses on the driver "maritime transport/port activities" while Table 6.2 focuses on the remaining drivers (energy sector, fisheries and aquaculture, marine tourism and recreation). Because the policy frameworks differ not only across but also within these drivers, we include subsectors, where the specific pressures differ enough that they require differentiated policy approaches. For example, maritime transport and port activities is broken into tankers, non-tankers, port activities and leisure boating as each of these subsectors demand different policy responses.

We label policy responses with abbreviated names (see Appendix B for a list of abbreviations) and divide them into international (I), regional (R), and national (N) responses. These tables provide an overview and assume the reader is familiar with the key policies. The underlying ABCD reports provide more detailed information for these policies and are identified in the tables below as follows:

- (A) = Source of detailed information found in the A report, see subsection "Summary of policy influence".
- (B) = Source of detailed information found in the B report, see Section 4.5 on driving forces.
- (C) = Source of detailed information found in the C report, see the ”Policies to manage and prevent oil spill damages” part of the C report.
- (D) = Source of detailed information found in the D report, see Chapter 4 on policy instruments.

A number of general conclusions from Tables 6.1 and 6.2 include the following:

- A key driving force is the rapid and consistent growth of the transport sector, whose growth does not appear hindered by existing environmental regulations.

- The maritime transport sector is governed almost exclusively by international regulations and national sector-specific rules are not an option. Further, ships at port cannot be targeted with national legislation, however incentive based voluntary systems can be relied upon.

- Certain policies responses are more aggressive than others. While there are a lot of policies related to oil spills, there are essentially no policies yet to address the threat of aquaculture (Table 6.2).

- Many of policy responses are overlapping. For example, a massive amount of international, regional and national legislation address the threat of operational oil spills (and to a less extent accidental oil spills) from the maritime transport sector. Because some of the international and regional legislation is actually implemented on the national level, the long list in Table 6.1 may overestimate the true policy response.

- In recent years air pollution has become a greater concern across all four drivers/pressures (Tables 6.1 and 6.2).

- Policies aimed at the sewage problem have increased in recent years to address eutrophication concerns. The sewage problem is relevant across several drivers including recreational boating, holiday homes, fisheries, and transport.

- In theory, there are a number of regulations covering marine litter, but their effectiveness in practice appears limited (see below).

- The tables below do not include a row for the policy response to "noise" because it is relatively insignificant. Noise concerns can arise from, and impact, the experience of recreational boating. One piece of national legislation addresses this as an aside (SJÖFS 2005:4), but the primary purpose is primarily boater safety and emissions. However, noise concerns has led to the introduction of *hänsynsområden* (special consideration zones) as a result of decisions by County Administrative Boards with reference to SFS 1998:808, Chapter 7, 1 § (see e.g. Länsstyrelsen i Västra Götalands län, 2012). Underwater noise concerns for fish themselves are addressed in the EU's Common Fisheries Policy (CFP) for commercial fishing.

- An important regulation for holiday housing and commercial accommodation along the coast is the shoreline protection law (Env. Code SFS 1998:808, Chapter 7; recently changed based upon Government Bill 2008/09:119). The purpose of this regulation is mainly to preserve public access to the shoreline and protect shoreline nature against physical destruction, and is therefore only indirectly associated to the pressures listed in Table 6.2.

Table 6.1. Summary of key policy responses to address drivers/pressures on marine ecosystem services within maritime transport and port activities

Driving forces and policy response	Maritime transport and port activities			
	Tankers	Non-tankers[a]	Port activities	Leisure boating (B)
Driving forces (A, B, C, D)	- global preference for sea-based transport - increased global oil consumption - rapid growth of industry unaffected by environmental regulations			- econ. growth - weather - climate change
Policy Response				
Oil pollution **(C)**	(I) MARPOL (I) SOLAS (I) Intervention Convention (I) COLREG * (I) STCW (I) CLC (I) IOPC Fund (I) MARPOL (I) OPRC * (R) ELD (R) WFD (R) MSFD (R) Erika Package	(R) EU DSD (R) BSAP (R) Baltic Strategy (EU) (R) OSPAR (R) Bonn Agreement (R) Copenhagen Agree. (N) Marine Env. Reg. (N) MB (N) Swedish Maritime Code (N) Civil Protection Act (N) Ship Safety Act (N) Act on Pollution from ships (N) Transport of Dang. Goods Act	(I) Paris MOU (R) EU Port Reception Dir. (R) BSAP (N) Waste regulation (N) Act on pollution from ships	*Relevant regulation not yet on the books, cf. SOU 2011:82*
Haz/Toxic substances pollution (A)	(I) AFS Conv. (I) MARPOL Ann. I-IV (I) Basal Conv.	*See tankers*	*See tankers*	(N) SJÖFS 2005:4 (N) SFS 1996:18 (R) EU Dir 94/25
Air pollution **(A)**	(I) MARPOL Ann. VI (R) EU Dir. 2005/33 (N) SFS 2010:743 (N) SJÖFS 2008:5	*See tankers*	*See tankers*	
Sewage **(A, B)**	(I) MARPOL Ann. IV,V, VI (R) HELCOM (R) OSPAR (R) BSAP (I) BWM	*See tankers* (see also (B) for info on passenger ships)	*See tankers*	*Relevant regulation not yet on the books, cf. Transportstyrelsen (2011) and SOU 2011:82*
Marine litter **(D)**	(I) MARPOL, Annex V (garbage) (I) LC 1972 (I) UNCLOS (I) Agenda 21, J-burg	(I) CBD (I) UNEP GPA (R) EU Dir - MSFD (R) EU Dir - 2000/59	(R) EU Dir - 2004/12 (R) EU Dir - 1999/32 (N) MB	(N) TSFS 2010:96 (N) SFS 1980:789 (N) SFS 1980:424 (N) SJÖFS 2001:12
Non-native species introduction (A)	(I) BWM			n/a

[a] Non-tankers include cargo, passenger ships, cruise ships, ferries, and fishing vessels.
* All oil spill policies address operational and accidental spills except those with an asterisk (*) which address only accidental.
See Appendix B for abbreviations.
(I) = International policy response, (R) = Regional policy response, (N) = National policy response, (A, B, C, D) = refers to source of information for the policy, see text above.

n/a = policy response is not directly relevant for this activity.

Table 6.2. Summary of key policy responses to address drivers/pressures on marine ecosystem services within energy sector, fisheries and aquaculture, and marine tourism and recreation.

Driving forces and policy response	**Energy sector**		**Fisheries and aquaculture**		**Marine tourism and recreation**
	Cables/pipelines	Offshore-wind	Commercial fishing	Aquaculture	Holiday housing and commercial accommodation
Driving forces (A, B, C, D)	- increased global demand for (renewable) energy - need to connect producer countries to consuming countries	- policies to stimulate development (ETS, Electricity Certificates)	- significant economic decline in industry in Baltic & NE Atl. - political will of member states to enforce quotas	- rapidly growing industry	- international visitation to Sweden - globalization & increased standards of living - taxes/regulations - climate change - weather
Policy response					
Oil pollution (C)	(R) Bonn Agreement (R) Espoo Convention		*See non-tankers in Table 6.1*	*Relevant regulations not yet on the books*	n/a
Haz/Toxic substances pollution (A)	(N) SFS 2010:900 (N) Env. Code (N) SFS 1998:808 (R) EU WFD	(N) SFS 2010:900 (N) Env. Code	n/a	*Relevant regulations not yet on the books*	n/a
Air pollution (A)	n/a	n/a	n/a	n/a	n/a
Sewage (A, B)	n/a	n/a	n/a	*Relevant regulations not yet on the books*	SFS 1998:899 NFS 2006:7 SFS 2006:412 SFS 1973:1149
Marine litter (D)	See Table 6.1		(I) FAO Code, see also Table 6.1	*Relevant regulations not yet on the books*	See Table 6.1
Non-native species introduction (A)	n/a	n/a	n/a	*Relevant regulations not yet on the books*	n/a
Fishing pressure regulations (A)	n/a	n/a	MSFD BSAP WFD OSPAR	n/a	n/a

See Appendix B for abbreviations.
(I) = International policy response, (R) = Regional policy response, (N) = National policy response, (A, B, C, D) = refers to source of information on policy, see text above.
n/a = policy response is not directly relevant for this activity

6.1.2 Effectiveness of existing policy response

Table 6.3 provides the basis for a crude analysis of the effectiveness of the *existing* policy response in a BAU perspective. Section 6.4.5 provides a detailed discussion of *future* policy response. A more detailed analysis would consider various factors that may determine the effectiveness of policies on the regulated community (e.g., type of approach (incentive-based vs. command and control), type of framework (guidelines/action plans, legally-binding, voluntary frameworks, etc.), driving forces, etc. However, we summarize the assessment from the underlying reports and discuss the general expectations around each of the main policy responses.

- **Oil pollution (C).** Because oil spill regulations are well established (dating to 1973), it bolsters recognition and ensures consistent enforcement. The existing overlap makes it difficult to determine which policies are most effective, although some of the most noteworthy policies for addressing accidental spills are MARPOL (an international treaty whose parties represent 99% of the world merchant shipping tonnage, including Sweden) and SOLAS and COLREG which both aim to prevent shipping collisions. HELCOM's Baltic Strategy has proven particularly effective in reducing ship-generated waste based on a proven reduction in illegal oil discharges seen from surveillance flights. Similarly, HELCOM's BSAP is expected to improve upon this record as it relies on satellite images to identify and then prosecute violators (Tables 4.1-4.3 in the C report). *We suggest that despite the fairly aggressive policy response to oil spills, additional requirements may be needed to reach GES given the continued and drastic increase in oil transport through the Baltic and NE Atlantic, particularly for port activities.*

- **Haz/Toxic substances pollution (A).** As noted above, environmental regulations are increasing on the maritime transport sector, but the policy response is not as aggressive here as it is with respect to oil spills. For example, most regulations are relatively new and future enforcement is uncertain. For example, the relatively new AFS was required to address the release of toxic and hazardous substances being released from ships at port. Further, MARPOL addresses the possibility of potentially major impacts from a tanker collision. *As with oil pollution, we suggest that the existing policy response may need to be augmented to reach GES given the rapid growth in the transport sector.*

- **Air pollution (A).** The air pollution in some Swedish ports currently exceeds air quality standards, which may prevent some of these ports from expanding. The relatively new air pollution requirements are expected to reduce sulfur content in fuel and thus reduce atmospheric deposition. *We suggest that the existing policy response is generally adequate, but the evolution of drivers should be monitored closely.*

- **Sewage (A, B).** A number of recent initiatives underscore the importance of addressing the sewage problem, particularly in the Baltic. Given the size of the problem -- nearly all drivers contribute in some fashion to this pressure -- *we suggest that the existing policy response is generally inadequate and additional policies may be needed to reach GES.*

- **Marine litter (D).** Policies addressing marine litter have been ineffective, perhaps due to a lack of understanding of the applicability of the regulations to different sectors. *We suggest that existing policy response is generally inadequate and additional policies may be needed to reach GES.*

- N**on-native species introduction (A).** The only policy addressing this is the BWM Convention (2004) which recently came into force and is expected to have a positive impact on reducing unwanted introductions. The problem itself has been long-recognized and requires significant, diligent, and costly actions on the part of the marine transport sector to implement successfully. *We suggest that existing policy response is generally adequate, but diligent enforcement is required to ensure GES.*

- **Fishing pressure regulations (A).** In contrast to the long-established oil spill policies, fishing pressure policies are relatively new and enforcement is sporadic, making it difficult to assess effectiveness. Further, the policy framework is very complex, making it difficult to determine net effect of quotas, allowable catch, capital restrictions and willingness to enforce regulations by national authorities. In theory these measures can reduce fishing pressure, but the political will of EU Member States will determine actual effectiveness. *Thus it is difficult to assess whether GES will be reached.*

- **Noise (D).** The noise problem affects both resource users and species themselves and is only addressed indirectly in existing policies. *Future regulations could strengthen this policy approach.*

Table 6.3. Effectiveness of *existing* policy responses to address pressures on ecosystem services arising from key drivers.

Policy response	Maritime transport and port activities				Energy		Fisheries and aquaculture		Marine tourism and recreation
	Tankers	Non-tankers	Port activities	Leisure boating	Cables/ pipelines	Offshore-wind	Commercial fishing	Aqua-culture	Holiday housing and commercial accom-modation
Oil pollution (C)	-	-	-	+/-	+	+	+/-	- [a]	n/a
Haz/Toxic substan-ces pollu-tion (A)	-	-	-	n/a	+/-	+	n/a	- [a]	n/a
Air pollution (A)	+	+	+	+	n/a	n/a	+	n/a	n/a
Sewage (A. B)	-	-	-	-	n/a	n/a	+	- [a]	-
Marine litter (D)	-	-	-	-	-	+/-	-	- [a]	+/-
Non-native species introduce-tion (A)	+	+	+	n/a	n/a	n/a	+/-	- [a]	n/a
Fishing pressure regulations (A)	n/a	n/a	n/a	n/a	n/a	n/a	+/-	n/a	n/a

[a] Currently there is no policy response related to the impact of aquaculture on ecosystem services.
Legend
(+) = existing policy measures considered *effective* against existing threats
(+/-) = effectiveness of existing policy measures *hard to determine*
(-) = existing policy measures considered *inadequate/ineffective/nonexistent* against existing threats
n/a = policy response is not directly relevant for this activity

6.2 Development of drivers until 2020 and 2050

Tables 6.1 and 6.2 above indicate that a common driving force behind the policy response for all drivers/pressures is global economic growth and the subsequent demand for oil consumption. In general these forces are anticipated to continue through 2020 and 2050. Below we provide more specific conclusions across each driver as defined in Tables 6.1-6.3 and associated pressures as defined in Chapter 4.

The drivers' influence on pressures in a BAU scenario to 2020 and 2050 is indicated in Tables 6.4 and 6.5. This analysis is based on the assessments in the ABCD reports, in particular the following parts:

A. The chapter on ”Identification of pressures of the maritime sector”.
B. Section 4.5, in particular Table 4.21 in Section 4.5.3.
C. The part of the C report that is about ”Maritime activities that could cause oil spills”.
D. Section 5.1.

The analysis in Table 6.4 and 6.5 is also based on the following additional considerations:

- For this synthesis we focus on the development of pressures considered to be *major*. We follow a conservative approach similar to the procedure for assigning minus and plus signs in Table 4.7 (recall that these signs were based on the signs in Tables 4.3-4.6). That is, for any given driver, a pressure was indicated as “major” in Tables 6.4 and 6.5 if at least one of the sub-pressures was assessed as major in the ABCD reports.

- Similar to the A Report, Tables 6.4 and 6.5 denote the development of pressures by using the following arrows:
  - ↑ denotes an increasing pressure
  - ↗ denotes an increasing pressure, less rapid than ↑
  - → denotes a pressure at approximately stable levels
  - ↓ denotes a decreasing pressure
  - R after an arrow denotes that risk is an important element of a pressure, e.g. because of accident risks

- A conservative approach was also chosen for the *development* of the major pressures over time in the sense that the arrows in Tables 6.4 and 6.5 denote the *most increasing* development found in the ABCD reports among the sub-pressures, for any given driver. That is, one ↑ dominates over ↗, one ↗ dominates over →, and one → dominates over ↓.

- The approximately stable pressure assigned to non-tankers (under oil spills) is based on the prediction in the C report that while there is an increasing risk for pollution accidents, the risk for fuel-related oil spill is diminishing because of a shift in the use of fuel.

- The pressure from holiday housing and commercial accommodation is assessed as major for physical damage and loss, and eutrophication. For physical damage and loss, this is partly explained by the fact that this pressure includes marine litter as a sub-pressure. For eutrophication, the assessment as “major” took into account the fact that holiday housing and commercial accommodation as a driver does not only include holiday housing and commercial accommodation situated at the shoreline, but also parts of inland holiday housing and commercial accommodation. See the definitions of marine recreation and tourism in the B report.

Table 6.4. The effects on pressures of the development in drivers, BAU 2020.

<table>
<tr><th rowspan="3">Pressures</th><th colspan="9">Drivers</th></tr>
<tr><th colspan="4">Maritime transport and port activities</th><th colspan="2">Maritime energy sector</th><th colspan="2">Commercial fisheries and aquaculture</th><th>Marine tourism and recreation</th></tr>
<tr><th>Tankers</th><th>Non-tankers</th><th>Port activities</th><th>Leisure boating</th><th>Cables/ Pipelines</th><th>Offshore-Wind</th><th>Commercial fishing</th><th>Aquaculture</th><th>Holiday housing and commercial accommo-dation</th></tr>
<tr><td>Physical damage and loss, incl. physical disturbance</td><td colspan="2">↑</td><td>↑</td><td>→</td><td>↗</td><td>↑</td><td>→</td><td></td><td>→</td></tr>
<tr><td>Hazardous substances and release of substances</td><td colspan="2">↑</td><td>↑</td><td>→</td><td>↗R</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Oil spills</td><td>↑R</td><td>→R</td><td>↑</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>Eutrophi-cation</td><td colspan="2">↑</td><td>↑</td><td></td><td></td><td></td><td></td><td>↑</td><td>→</td></tr>
<tr><td>Biological disturbance</td><td colspan="2">↑R</td><td></td><td></td><td></td><td></td><td>↑</td><td></td><td></td></tr>
<tr><td colspan="10">Legend
↑: increasing and major pressure
↗: increasing and major pressure, less rapid than ↑
→: major pressure at approximately stable levels
↓: decreasing and major pressure
R: risk is an important element of a pressure, e.g. because of accident risks
Shaded cell: pressure is not judged as major</td></tr>
</table>

Table 6.5. The effects on pressures of the development in drivers, BAU 2050.

Pressures	**Drivers**								
	Maritime transport and port activities				**Maritime energy sector**		**Commercial fisheries and aquaculture**		**Marine tourism and recreation**
	Tankers	Non-tankers	Port activities	Leisure boating	Cables/ Pipelines	Offshore-Wind	Commercial fishing	Aquaculture	Holiday housing and commercial accommo-dation
Physical damage and loss, incl. physical disturbance	↑		↑	↗	↗	↑	↓		↗
Hazardous substances and release of substances	↑		↑	↗	↗R				
Oil spills	↑R	→R	↑						
Eutrophi-cation	↑		↑					↑	↗
Biological disturbance							↓		

Legend
↑: increasing and major pressure
↗: increasing and major pressure, less rapid than ↑
→: major pressure at approximately stable levels
↓: decreasing and major pressure
R: risk is an important element of a pressure, e.g. because of accident risks
Shaded cell: pressure is not judged as major

6.3 Implications for GES indicators and ecosystem services

Below we conclude what the projections in Section 6.2 imply for the GES indicators selected in Chapter 5 and associated ecosystem services.

6.3.1 D1 Biological diversity

6.3.1.1 DISTRIBUTIONAL RANGE

According to the previous analysis, the distributional range of marine species is mostly affected by extraction, eutrophication and non-indigenous species.

Extraction of species by commercial fisheries is expected to increase up to 2020 but decrease afterwards due to implementation of the Common Fishery Policy. Increasing fishing pressure may also increase the pressure on eelgrass meadows if decreases in predatory species allow populations of grazing species to grow.

Nutrient emissions from maritime transports and port activities are expected to increase up to 2020 and to a smaller extent up to 2050. Nutrient emissions from tourism, on the other hand, will likely increase more to 2050 than to 2020. In total, nutrient emissions and eutrophication due to maritime activities are expected to increase up to 2020 as well as 2050.

Impacts from non-indigenous species resulting from maritime transports are expected to increase up to 2020 but not up to 2050.

For eutrophication of the sea the marine sector is less dominant compared to other activities than in the case of extraction of species and spreading of non-indigenous species. This implies that trends for the latter two may be more important for the sum of pressures from the maritime sector. We therefore conclude that the status indicator 1.1.1 Distributional range will probably deteriorate up to 2020, but after that remain constant up to 2050.

6.3.1.2 POPULATION ABUNDANCE AND/OR BIOMASS

Extraction of species, hazardous substances and non-indigenous species are among the impacts on population densities and biomasses from the maritime sector.

As stated in the previous section extraction of species by commercial fisheries is expected to increase up to 2020 but thereafter decrease up to 2050. Hazardous substances from maritime transports and port activities are expected to increase during the whole period. Impacts from non-indigenous species resulting from maritime transports are expected to increase up to 2020 but not up to 2050.

Extraction of species is considered the most important factor related to maritime activities influencing population numbers, but hazardous substances and non-indigenous species may be significant as well. Since hazardous substances from the maritime sector are expected to increase up to 2020 we conclude that the status indicator 1.2.1 Population abundance and/or biomass will deteriorate until 2050 in a BAU scenario.

6.3.1.3 CONDITION OF THE TYPICAL SPECIES AND COMMUNITIES

Conditions of typical species and communities are considered to be influenced by abrasion of bottom substratum, eutrophication and oil spills from the maritime sector.

From the energy sector the abrasion from construction of pipelines will increase slightly up to 2020 and 2050. Abrasion from bottom trawling related to fisheries is considered to follow the trends in fishing pressure and increase up to 2020 but decrease after 2050.

As concluded above the nutrient emissions and eutrophication due to the sum of maritime transport, port activities and tourism are expected to increase up to 2020 as well as 2050. Oil spills are expected to increase up to 2050.

In total the status indicator 1.6.1 is considered to deteriorate up to 2020 and 2050 in a BAU scenario.

6.3.1.4 RELATIVE ABUNDANCE AND/OR BIOMASS

Abundance of eelgrass meadows and other benthic habitat is believed to decrease as an effect of bottom trawling, construction works and eutrophication. According to our analysis most of these factors increase their impact until 2020 and 2050 in a BAU scenario (see above).

Hence we conclude that the status indicator 1.6.2 Relative abundance and/or biomass deteriorate until 2020 and 2050 in the BAU scenario.

6.3.1.5 PHYSICAL, HYDROLOGICAL AND CHEMICAL CONDITIONS

This indicator may be affected by climate change, eutrophication and non-indigenous species, although we have not considered climate change to be a pressure related to the maritime sector in this report.

Trends for oil spills, eutrophication and non-indigenous species are mostly increasing. In this respect not only nutrients but also organic matter enrichment from aquaculture and maritime transports negatively affect the oxygen conditions in bottom waters. The impact of non-indigenous species on the physical conditions, however, is not exclusively negative as the example with *Marenzelleria neglecta* demonstrates (see section 5.2.1.5). In all, we conclude that trends for the indicator 1.6.3 Physical, hydrological and chemical conditions is negative for the whole period up to 2050.

6.3.1.6 IMPLICATIONS FOR THE SUPPLY OF ECOSYSTEM SERVICE S4 DIVERSITY

Trends for all considered indicators of the descriptor D1 Biological diversity, which also describes the ecosystem service S4 Diversity, show more or less negative trends. This implies that the supply of S4 will also decrease to 2020 and 2050 in a BAU scenario. This further implies that the status of S4 will remain *insufficient* if business remains as usual.

6.3.2 D5 Eutrophication

6.3.2.1 NUTRIENTS CONCENTRATION IN THE WATER COLUMN

According to the previous analysis high nutrient levels and eutrophication is mainly an issue in southern Sweden along the coast of Skagerrak, Kattegat and the Baltic Proper. Along the coast in the Gulf of Bothnia there are just a few spots where eutrophication is a problem. Tables 6.4 and 6.5 indicate that nutrient emissions from maritime transports and port activities are expected to increase up to 2020 and to a smaller extent up to 2050. Nutrient emissions from tourism, on the other hand, appear to increase more up to 2050 than to 2020. Furthermore, nutrient emissions from aquaculture are also expected to increase rapidly to 2020 and 2050. Hence, in total it can be concluded that the indicator 5.1.1. Nutrient concentration in the water column is expected to increase both in the short run (2020) and in the long run (2050) under the BAU scenario. It is also important to keep in mind that a number of human activities causing pressures on the marine environment are not included here, e.g. agriculture which causes major nutrient emissions. See Table 3.1 on excluded human activities.

6.3.2.2 SPECIES SHIFT IN FLORISTIC COMPOSITION

The only part of the indicator considered here is toxic algal blooms. Toxic algal blooms are the most obvious ways in which eutrophication affects marine recreation and are often measured in terms of amount of cyanobacteria accumulated at the sea surface. According to the previous analysis it can be concluded that cyanobacteria mostly occur in the Baltic Sea, and only occasionally in the Gulf of Bothnia. Furthermore, the variation from year to year is large. Since toxic algal bloom events are linked to eutrophication it can be concluded that the indicator 5.2.4. Species shift in floristic composition is expected to increase both in the short run (2020) and in the long run (2050) under the BAU scenario. Again, as for the case of nutrient concentration in the water column, it is important to keep in mind that a number of human activities causing pressures on the marine environment are not included.

6.3.2.3 IMPLICATIONS FOR THE SUPPLY OF ECOSYSTEM SERVICE R3 EUTROPHICATION MITIGATION

Trends for the two considered indicators of the descriptor D5 Eutrophication which also describe the ecosystem service R3 Eutrophication mitigation show negative trends. This implies that the supply of R3 will decrease with time up to 2020 and 2050 in a BAU scenario. This further implies that the status of R3 will remain *insufficient* in the North Sea and the Baltic Sea if business remains as usual.

6.3.3 D8 Contaminants

6.3.3.1 OCCURRENCE, ORIGIN, EXTENT OF SIGNIFICANT ACUTE POLLUTION EVENTS

The probability for oil spills is increasing with increasing traffic. The risk is particularly increasing for tanker accidents, due to an expected heavy growth in tanker traffic in the Baltic Sea and Northeast Atlantic. For non-tanker accidents (i.e. spills of bunker oil), the probability is also increasing due to an expected growth in traffic, but there is also a trend in shipping to replace fossil fuel with liquefied natural gas (C report), which lowers the risk for bunker oil spills. In general, however, the risk for oil spills is expected to increase dramatically under BAU, both until 2020 and until 2050.

For implications for C2 scenery, see Section 6.3.4.2.

6.3.4 D10 Marine litter

6.3.4.1 TRENDS IN THE AMOUNT OF LITTER WASHED ASHORE AND/OR DEPOSITED ON COASTLINES

According to previous analysis (Section 5.2.4), it can be concluded that marine litter on beaches is a larger problem in the North Sea than in the Baltic Sea, although it is important to keep in mind that the local variations can be substantial. Tables 6.4 and 6.5 indicate an increasing trend for marine litter (which is part of the pressure “Physical damage and loss including physical disturbance”) in the BAU 2020 and BAU 2050 scenarios. This increasing and major pressure of marine litter in BAU 2020 is primarily due to expected increased activities in the maritime transportation and maritime energy sectors. The BAU 2050 scenario implies increased activities in the maritime transportation and maritime energy sectors, but also more intensified marine tourism and recreation activities and leisure boating. This together implies that the BAU 2050 scenario for marine litter will lead to further deterioration compared to BAU 2020.

6.3.4.2 IMPLICATIONS FOR THE SUPPLY OF ECOSYSTEM SERVICE C2 SCENERY

The considered indicator of the descriptor D10 Marine litter, and descriptor D8 Contaminants, which also describes the ecosystem service C2 Scenery, show negative trends. This implies that the supply of C2 will decrease with time up to 2020 and, even more, to 2050 in a BAU scenario. However, the local variations may be substantial. This further implies that the status of C2 will remain *locally insufficient* in the North Sea and the Baltic Sea if business remains as usual.

6.4 Cost of degradation

Based on the evaluation in Section 6.3, we discuss the impact on human welfare. The impact is based on a comparison between a BAU scenario and a scenario of reaching GES for each of the descriptors presented in Section 6.3. We also discuss main gaps in data, and what might be needed in terms of additional policy response to reach GES. We assume the reader is familiar with terminology connected to economic valuation of the environment, as well as the cost of degradation concept (see the C report for an overview). It is important to emphasize that since GES is not yet defined in quantitative terms, the actual size of the cost of degradation is consequently unknown.

First, we provide a general mapping of the links between different types of ecosystem services in order to be able to draw conclusions regarding which types of values will be affected from degradation in the descriptors D1 Biological diversity, D5 Eutrophication, D8 Contaminants and D10 Marine litter. In Figure 6.1, a schematic illustration is presented, showing some of the main linkages between regulating, supporting, provisioning and cultural services. Regulating services and supporting services provide a foundation for the functioning of the ecosystem and a positive or negative change in one of these services is likely to affect the other regulating and supporting services. For example, a change in the extent of the regulating service R3 Eutrophication mitigation is likely to affect supporting services such as diversity and resilience.

Regulating and supporting services serve mainly as intermediate services for the provisioning and cultural services, cf. Table 4.1. The provisioning services provide further benefits to industries such as fishery, energy production and extraction of other resources. In Figure 6.1, the provisioning services have been divided into two groups. The group on the right hand side represents provisioning services that are mainly final, perhaps with low or no intermediate function. These services provide end benefits to industries. The group on the left hand side of provisioning services represents services that both provide end benefits to industries (e.g. shipping and fishery), and have an intermediate function towards cultural services such as scenery, recreation and the legacy of the sea.

The cultural services, further, are either final services to the public, or intermediate services to other cultural services. For example, recreation is a final service but might also be considered an intermediate service to the maintenance of cultural heritage, or vice versa.[1]

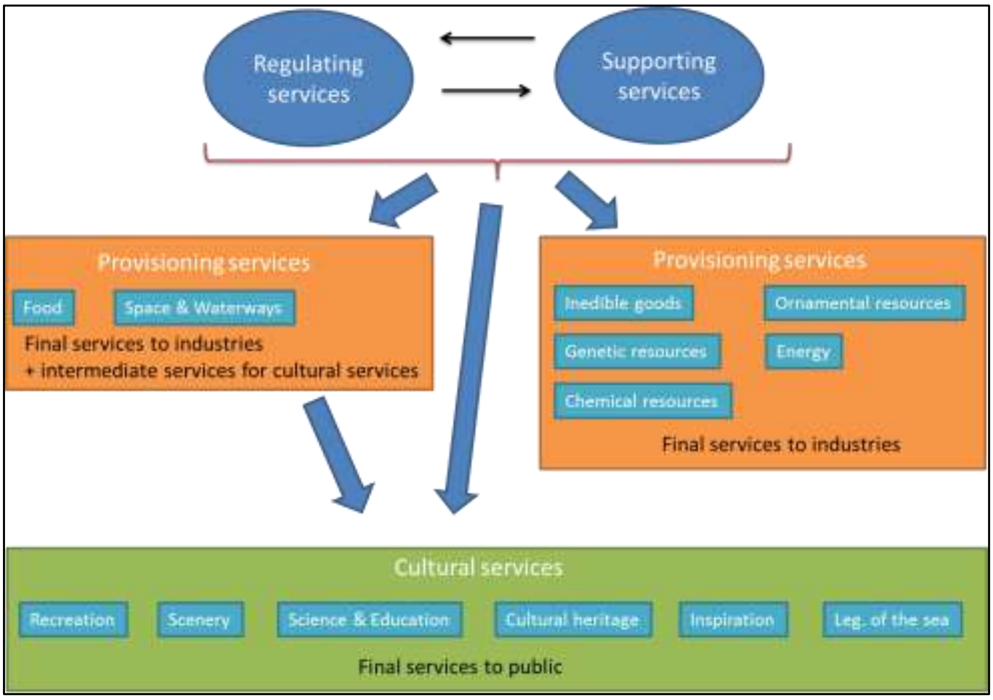

Figure 6.1. Linkages between ecosystem services.

The exercise in Figure 6.1 provides a general conclusion: The same particular ecosystem service can be considered either final or intermediate, depending on type of use. This has consequences for a cost of degradation analysis.

Below, we discuss the cost of degradation for each of the descriptors D1 Biological diversity, D5 Eutrophication, D8 Contaminants and D10 Marine litter, respectively, with the mapping of Figure 6.1 in mind.

6.4.1 D1 Biological diversity

6.4.1.1 AFFECTED ECOSYSTEM SERVICES

The descriptor D1 Biological diversity could be considered to measure the status of the supporting service S4 Diversity, and its status affects potentially all other ecosystem services to various extents. For example, diversity affects the provisioning of food, genetic resources and chemical resources. Further, it

[1] It could be discussed whether provisioning services represent mainly benefits to industries, and cultural services represent mainly benefits to the public – well-functioning markets for e.g. seafood are obviously also a benefit to the public. However, perhaps one can argue that the “first step” is a benefit to an industry, which may also give benefits to the public. For the cultural services, industries such as tourism are obviously also affected. Again, it is probably reasonable to argue that, possibilities for recreation attract the public, which in turn provide possibilities for industries to benefit.

affects cultural services directly through the effect on scenery and recreational possibilities.

6.4.1.2 WHAT DO WE KNOW ABOUT THE COST OF DEGRADATION?

Effects from reduced diversity on provisioning services
The provisioning services most likely to be affected by reduced diversity are food, inedible goods, genetic resources and chemical resources. Regarding food, several studies have attempted to estimate the value of different types of fisheries, see the C report. For example, Döring et al. (2000) estimate that a hypothetical recovery of the cod stock could be worth 28 000 euros per year per vessel and HELCOM and NEFCO (2007) estimate the total annual value of fish caught in the western Baltic Sea to 1,5 billion euros. The effect on fisheries from reduced biodiversity, however, is hard to estimate and perhaps has to be estimated on a case by case basis.

Effects from reduced diversity on cultural services
All cultural services are likely to be affected by reduced diversity. For example, if the provisioning of recreational fishery species (i.e. 'food') is reduced, the value of recreational fisheries (i.e. 'recreation') is in turn reduced. Further, scenery might be affected by reduced diversity, which in turn affects the utility derived from recreational activities. Also inspiration, science and education and cultural heritage might be affected. Last but not least, the legacy of the sea is affected because a healthy ecosystem provides existence values. A conclusion from SEPA (2008) is that diversity is primarily valued indirectly through the effect on other ecosystem services, and the existing literature on cultural services focuses largely on the value of various types of recreation and the legacy of the sea. There are several examples of values of recreation and the legacy of the sea in SEPA (2008) but these studies are hard to link to the diversity indicators.

To our knowledge, there are no studies available regarding the value of inspiration, science and education, or cultural heritage connected to the state of the Baltic Sea.

6.4.2 D5 Eutrophication

6.4.2.1 AFFECTED ECOSYSTEM SERVICES

D5 Eutrophication could be argued to describe the state of the regulating ecosystem service eutrophication mitigation. As with diversity, this ecosystem service provides a foundation for the functioning of the ecosystem. A reduced provision of this ecosystem service has a potential effect on all other ecosystem services. The main direct effects on end-benefits from ecosystem services due to eutrophication are probably related to food, recreation and the legacy of the sea. However, through the interactions of the supporting and regulating services, broader effects can also be expected. In addition, there is a potential for effects on other provisioning services, such as chemical and genetic resources. Finally, cultural services such as science and education, inspiration and cultural heritage are also affected by a reduced provision of eutrophication mitigation.

6.4.2.2 WHAT DO WE KNOW ABOUT THE COST OF DEGRADATION?

Effects from eutrophication on provisioning services
Several studies have assessed the value of the provisioning of food. However, the effects from eutrophication on this service are not very well-studied. Paulsen (2007) studies the impact from eutrophication on the provisioning of

food through its effect on shallow soft bottom habitats on the Swedish west coast. The cost is estimated to be 1-1.5 billion euros over a 55 year period. For other provisioning services, we have not identified studies that assess the effect from eutrophication.

Effects from eutrophication on cultural services
Cultural services are affected by eutrophication in several ways. Recreation and the legacy of the sea are the most well-studied ecosystem services related to eutrophication of the Baltic Sea and Northeast Atlantic. For marine tourism and recreation, the B report emphasizes that different types of recreational activities and marine tourism sectors are more or less sensitive to eutrophication effects. They conclude that water-based activities such as swimming and diving are the most sensitive to eutrophication, whereas the usage of water-based transportation is less sensitive. The activities that are sensitive to eutrophication are also those activities that will bear most of the cost of degradation. This, in turn, affects tourism sectors. Leisure boating, holiday houses, commercial accommodation and same-day visits are the sectors that are expected to be most heavily affected by a reduced demand for recreational activities due to a degraded environmental state.

In the B report, the cost of degradation analysis discusses what would be lost if BAU is reached instead of GES. The approach is supported by a literature review primarily based on SEPA (2008) which provides a comprehensive presentation of valuation results specifically linked to ecosystem services provided by the Baltic Sea and Skagerrak, but also based on other similar kinds of mapping such as HELCOM (2010) and Kinell et al. (2009). It is evident from the literature review that valuation studies dealing with ecosystem services in the Baltic Sea and Skagerrak are seldom linked to individual recreation activities. However, there are a number of studies dealing with recreation in general.

The review of valuation studies shows that eutrophication has been thoroughly studied. For example, Turner et al. (1999) estimate the value of reduced effluents of nitrogen and phosphorus to the Baltic Sea to be 4.5 billion euros. However it is difficult to separate the use vs. non-use (the legacy of the sea) values from this estimate. In other words, the value accruing through recreational use of the Baltic Sea cannot be identified. In general, however, the literature is at present not sufficient to estimate the cost of degradation, since the policy measures and results are often vaguely described in the valuation studies (as emphasized in SEPA, 2008).

The strongest link between the reviewed valuation studies and GES seem to be through the descriptor D5 (eutrophication), especially indicator 5.1.1 (nutrient concentration). Regarding inspiration, cultural heritage and science and education, the impacts from eutrophication has to our knowledge not previously been studied.

6.4.3 D8 Contaminants

6.4.3.1 AFFECTED ECOSYSTEM SERVICES

Indicator 8.2.2 (*Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution*) describes the effect from oil spills to the coastal scenery, and their impact on different organisms that are physically affected by an oil spill. An oil spill has two types of effects – the first being direct due to polluted coastlines, which affects living organisms and the possibilities for recreation – the second being more long-run, due to potential impacts on regulating and supporting ecosystem services.

The first type of effect mainly affects scenery, recreation and the legacy of the sea. As for the second effect, the impact to ecosystem services is more complex, and potentially all ecosystem services are affected. The extent to which an oil spill results in negative effects on ecosystem function is largely dependent on where and when the spill occurs, and how much and what type of oil is spilled.

6.4.3.2 WHAT DO WE KNOW ABOUT THE COST OF DEGRADATION?

Effects on provisioning services
Fishing is usually prohibited in an area where a large oil spill has occurred due to toxic contamination of fish. This represents an impact to the provisioning service food. The C report uses a cost estimate of 5-16 million euros to the fishery industry for an exceptional oil spill in southern Sweden, based on original estimations by Forsman (2003, 2006 and 2007). Another direct effect might be physical hindrances to traffic at sea. Further, if an oil spill has long-run effects to the ecosystem, this might also affect other provisioning services, such as inedible goods, genetic resources and chemical resources. For these types of effects, no cost estimates are available.

Effects on cultural ecosystem services
A major impact of an oil spill is likely to be on recreation. The damage cost from an oil spill can be expected to lead up to 13 million euros in lost value to recreational fisheries, see the C report. For beachside recreation, the C report considered a value of 130 SEK (15 euros) per lost recreational day, based on an original estimation by Kinell et al. (2009). However, there is no information available on the amount of lost recreational days. Further, there might be long-run effects to both recreational fishing and beachside recreation, if supporting and regulating services are disturbed in the long run. However, we have not identified any literature that supports this.

The legacy of the sea is expected to be affected by oil spills. Ahtiainen (2007) estimates the willingness to pay to reduce the risk for oil spills in the Gulf of Finland to 100-300 million euros. This estimate however reflects both use and non-use values, which means that it is hard to say how much of this value is related to the legacy of the sea.

The actual environmental costs of oil spills depend on factors such as season, location and amount and type of oil.

6.4.4 D10 Marine litter

6.4.4.1 AFFECTED ECOSYSTEM SERVICES

Litter affects ecosystem services in two ways: Through its physical effect on e.g. scenery and through the effect on ecosystem functions, the latter effect being most prominent when the litter is toxic. The physical effect mainly affects cultural ecosystem services, such as recreation and the legacy of the sea, but also potentially the provisioning of energy and space and waterways, since litter may get entangled in turbines in wave and tidal power plants, and may block narrow water passages. The effect through ecosystem functions potentially affects many or all other ecosystem services.

6.4.4.2 WHAT DO WE KNOW ABOUT THE COST OF DEGRADATION?

Effects on provisioning services
There is very little information available on the chemical effects of litter. However, this effect may influence the whole ecosystem, not least the provisioning of food. Further, inedible resources and chemical and genetic resources might be affected, but we have not identified studies supporting this. Relating to physical disturbances to space and waterways and the production of energy, we have not identified any estimates of the potential size of these costs. Regarding the provisioning of food, there is a risk that physical disturbances from litter may cause damaged equipment and reduced catches. The total cost for fouled propellers, blocked intake pipes, damaged nets and destroyed catch due to marine litter has been estimated to be 1 million euros per year along the Swedish west coast (Hall, 2000).

Effects on cultural services
The effect on cultural services is mainly through the negative impact from litter on scenery. This will potentially affect all cultural ecosystem services, but probably recreation and the legacy of the sea the most. There is not much literature available on the costs of these damages, but several studies indicate that the public have clear preferences towards reducing litter, and that beach cleaning constitutes a considerable cost. Estimates of the costs for beach cleaning are presented in the D report, see also e.g. Hall (2000) and Franzén et al. (2006).

The economic value of establishing special consideration zones on the Swedish east and west coasts has been estimated by Östberg et al. (2011). Establishing such consideration zones implies a number of recommendations, largely focusing on less noise and marine litter. The resulting economic value for the east coast was approximately SEK 500 per year and household, and SEK 900 per year and household for the west coast. A share of this value is due to reduced amounts of marine litter, although it unclear how large a share. Nonetheless this share could be interpreted as the cost of degradation if marine litter cannot be avoided.

From the literature review of valuation studies in the B and D reports, it became clear that few studies have dealt with marine litter specifically. Only one valuation study, Östberg et al. (2011), provide strong links to GES through the descriptor D10 Marine litter.

6.4.5 Potential future policy needs to reach GES

Given the ineffectiveness of the policy response to some pressures (see "-" in Table 6.3) as well as the forecasted increase in pressures (Tables 6.4 and 6.5), there is room for improvement of existing policies. The need for both new and improved policies is also underscored by the potential magnitude of welfare impacts under a BAU scenario (see Sections 6.4.1-6.4.4).

Identification of specific measures to avoid a BAU deterioration is beyond the scope of this study and requires in-depth study. The purpose of this section is to shed light on potential future policy needs by highlighting the pressures that may require additional scrutiny by policy makers. The actual future policies will evolve as the threats and pressures themselves are better understood, but the summary below suggests that innovative and more effective policies are possible -- indeed may be necessary -- in order to reach GES.

Based on the policy responses (rows) in Table 6.3 we identify the following policy improvements that may be needed to reach GES. Our focus is primarily on existing policies that are judged to have reduced effectiveness, i.e., "-" in Table 6.3.

- **Oil pollution**. Oil pollution policies in general are expected to become more stringent over time in response to the driving force of globalization and rapid economic growth in the transport sector. Future *improvement* in policies should target tankers and port activities, where environmental impacts can be significant. An example of a *new* policy that may be needed is increased requirements for compensatory restoration following oil spills or other damage. For example, although some land-based facilities are required to follow the strict compensatory requirements put forth by the EU's Environmental Liability Directive (ELD), these regulations specifically exempt activities covered by international regulations (e.g., tankers). International compensation regulations that apply to oil spills in the Baltic are far less stringent than those in the ELD and those found in the US. The motivation for increasing the stringency of compensatory requirements in the Baltic and NE Atlantic is that it may provide an additional incentive for polluters to undertake spill prevention measures by encouraging them to internalize the external costs of environmental repair (Carson et al., 2003; Fejes et al., 2011).

- **Haz/Toxic substances pollution**. Policies addressing hazardous and toxic substances may be required to address both air pollution – in particular the increasing impact at the harbors in Gothenburg, Stockholm, and Western Skåne – as well as the potential for collision of tankers carrying non-oil substances. As noted under oil spill policies, compensatory repair requirements for such accidents may represent a potential policy improvement in this area.

  It is important to re-iterate that any future policies aimed at the maritime transport sector (e.g., for oil or haz/toxic substances) must be an international effort, as national sector-specific rules are not an option. Further, ships at port cannot be targeted with national legislation, however incentive based voluntary systems can be relied upon.

- **Sewage**. Policies that address sewage are relevant across all of the four drivers, including holiday housing. Because of the fact that so many different activities contribute to the problem, future policies will likely be needed to reach GES. Policies should carefully target those activities that contribute most to eutrophication. One recent new policy initiative in the Baltic is a projected new rule in 2014 from Sweden's Transportstyrelsen that prohibits emissions from recreational craft.

- **Marine litter**. Despite a plethora of regulations targeting the three major drivers (shipping, fishing, recreation) the effectiveness of marine litter policies is limited. A recent survey of marine users indicated that very few are aware of the relevant rules, suggesting that existing policies may require better communication, see the D report. However, it is also possible that newer and stricter policies may be needed, such as imposing fines and penalties for violations. Because respondents to the marine litter survey indicated a desire for a strengthened policy response, public support may facilitate innovative improvements. Specific suggestions include increased provision of trash/recycling receptacles at beaches, improved information sharing, better enforcement, and improved clarification and definitions of the existing rules, see the D report for details.

In addition to the above, a number of other policy improvements may also be relevant, if less urgent.

- **Various policy responses – Aquaculture**. Currently there are no policies addressing threats from aquaculture in part because the sector is relatively small. However, there may be a need for policy responses depending on future growth. Given fast growth assumptions, GES deterioration could incur to a variety of indicators, including the ones studied in this report. Thus, while new policies may not be warranted immediately, this is an area that should be monitored closely.

- **Fishing pressure**. The current policy response is significant, but due to limited effectiveness future policy improvements may be needed. It is very difficult to assess future policy needs given the year to year variation in fish stock and the heterogeneous enforcement of regulations across countries. Certain stock have been severely impacted (e.g., cod), thus requiring continued policy attention.

Finally, it should be noted that several important drivers and associated pressures are not covered by this synthesis (see Table 3.1). Separate additional policies might be required to influence these drivers.

7 Concluding discussion

The purpose of this 'synthesis' report is to provide added value to the individual ABCD reports on which it mainly relies. Some of the main contributions of this synthesis report are the following:

- A clarification of the relationship between drivers and pressures studied in the ABCD reports, cf. Chapter 3 and Figure 3.1.

- A closer analysis of the joint influence of the studied human activities on the marine environment, and also the dependence of these activities on various ecosystem services, as per the ESR framework. This enabled in turn an improved basis for assessing the future development of selected indicators and the supply of ecosystem services and also the cost of degradation.

- A joint overview of policy instruments and their effectiveness is now available, which also turned out to be useful for a discussion on what policy change might be most critical for reaching GES.

While this is likely to give added value to the ABCD reports, the topics covered in the ABCD reports still constitute an important limitation of the synthesis: Its point of departure is a finite and perhaps incomplete set of human activities associated with maritime transport, port activities, marine energy sector, commercial fisheries and aquaculture, and marine tourism and recreation. While all these activities are relevant as drivers for pressures on the marine environment, there are in some cases *other* human activities that account for a substantial influence on the marine environment. For example, other drivers, such as agriculture and non-maritime industry, have a major influence on marine eutrophication and the presence of hazardous substances in the marine environment, cf. Table 3.1. The results of the synthesis have to be interpreted with its selection of drivers in mind.

The work for this report was based on an ecosystem service approach, and the ecosystem service analysis that was carried out followed the steps of a Corporate Ecosystem Service Review (ESR) as outlined by WRI (2008). One of the most important features of an ecosystem service approach is that it provides a meeting point for measures of environmental change and how these measures affect human well-being (see "ecological endpoints" below). Changes in human well-being can in turn be assessed by methods measuring total economic value (TEV) (or by non-economic methods). Some main advantages of ESR in the context of this report are its emphasis on *both* the dependencies *and* the impacts of human activities on ecosystem services, and its simple approach of efficiently screening out the ecosystem services of greatest importance in terms of dependencies and impacts. Without condensing the information set this synthesis would likely be subject to the "cannot-see-the-forest-for-the-trees" problem. Such screenings have also been necessary for the selection of GES descriptors and associated indicators.

However, this simplified approach inevitably has a downside. Combining several screenings might imply that potentially important interrelationships among factors are neglected. For example, factors that are sorted out in different stages of the screening procedure might together have synergies that are not taken into account. This weakness is one reason why the results are characterized by uncertainty. In addition, there is a general need for information that is suitable for describing the status of ecosystem services, and

GES descriptors and indicators. Our assessments are often based on observations about individual species or substances, and in many cases we also have to rely on studies of particular coastal areas because of a lack of general studies on the entire marine system. As a consequence, we have relied on a qualitative analysis and applied conservative approaches. While this may lead to more robust results, it does not remove a fundamental uncertainty due to lack of information.

A particular uncertainty is associated with the concept of ecosystem services. While projects such as MA (2005) and TEEB (2010) have greatly improved the conceptual understanding of nature's provision of ecosystem services, the meeting point between measures of environmental change and how these measures affect human well-being is still relatively 'unoccupied' in the sense that there are very few studies that demonstrate a quantitative link between environmental change and the supply of various ecosystem services. Naeem (2011) suggests this may be because ecological research traditionally has another focus than providing measures that can be easily linked to well-being. The C report highlights the importance of finding useful ecological endpoints, i.e. biophysical measures that can serve as a basis for valuing changes in the supply of ecosystem services. Such endpoints would serve as convenient meeting points for ecologists and economists, see SAB (2009) and Boyd (2010). This explains why this type of an ecosystem service analysis tends to be qualitative and to a large extent based on professional judgments. There is thus a need for studies allowing a more quantitative analysis, which is likely to require, *inter alia*, more precise definitions of the various ecosystem services. For example, a step towards this might be the division of the broad ecosystem service C1 Enjoyment of recreational activities into seven subcategories C1.1-C1.7, see Section 2.1. Further efforts to provide precise definitions of other ecosystem services besides recreation would greatly facilitate assessments of the economic (and social) consequences of programs of measures, such as those PoMs which will be a part of the MSFD implementation.

A particular contribution of this report is to point at existing gaps between ecosystem services and GES descriptors and indicators. While an ecosystem service approach provides a helpful link between the environment and human well-being, the analysis indicates that the approach is not fully compatible with the present GES descriptors and indicators. For example, the intermediate ecosystem service C2 Scenery is only incompletely reflected in the GES descriptors. This reflects the fact that GES descriptors tend to have a focus on ecological factors. This makes sense, but it also entails a drawback: The selection of associated indicators might not be those which are suitable from the 'meeting point' perspective discussed above.

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Appendix A. Definitions of ecosystem services

Definitions in Garpe (2008) of the marine ecosystem services listed in Table 2.1 are collected below.

A.1 Supporting ecosystem services

S1 Maintenance of biogeochemical cycling

"Biogeochemical cycling refers to the cyclical movement of energy and materials within ecosystems. This cycling is essential for the provision of construction material for all living things, including the resources used and valued by society. For example, all water, carbon and nitrogen making up the human body, as well as all other animals and our entire living world, are part of the biogeochemical cycle. Not only do these chemical elements move through living organisms, in this sense referred to as exchange pools. They also move through water, land and air. Hence the biogeochemical cycle is the pathway by which chemical elements move through the physical and biological compartments of all ecosystems. The cycle is a closed one and hence Earth does not receive refills of nutrients; in effect, all elements are recycled. However, some chemicals are held or accumulated for long periods of time in one place, this place being referred to as sink or reservoir. Examples of long-term storage include our coal and oil reservoirs, deposited millions of years ago." (Garpe 2008, p. 32).

S2 Primary production

"Primary producers use solar energy to convert dead material (inorganic) to living material (organic) material by means of photosynthesis. There are three main types of primary producers in our marine environment: 1) Phytoplankton in the water column, 2) Benthic algae and sea-grass, 3) Coastal vegetation (e.g. reed)." (Garpe 2008, p. 38).

S3 Maintenance of food web dynamics

"Food webs attempt to describe trophic relationships between organisms (i.e. who eats who). By means of food webs nutrients are transferred from plankton to the resources that are valued by society. An organism's position within a particular food web is defined by its function (e.g. whether it is a primary producer, feeds on animals or extracts nutrients from dead organisms)." (Garpe 2008, p. 41).

S4 Maintenance of biodiversity

"Biological diversity, or biodiversity for short, refers to the variety of life forms at all levels of organization from the molecular to the landscape level. A variety of species performing a plethora of functions are essential for most ecosystem services. Of direct benefit to society is the supply of various species for consumption. Of indirect benefit is the maintenance of resilience. Out of convenience, biodiversity typically refers to a function of the number of species and the number of individuals of each species in a given area. Functional diversity is an important aspect of biodiversity which refers to variation among ecological functional processes (often related to feeding patterns or interactions among species) within an ecosystem. It should be kept in mind that genes, species, ecological functions and ecosystems are not equal - some are indeed more important than others." (Garpe 2008, p. 49).

S5 Maintenance of habitat

"Marine habitat typically refers to benthic or littoral habitat structure and habitat forming biota. In a broader perspective, habitat is simply the environment in which an organism occurs. From this definition, it should be obvious that habitats – of all kinds - are essential to maintain ecosystem diversity and function. Nevertheless, some habitats are often highlighted as of particular value. For instance, structurally complex habitats like algal beds or biogenic reefs, as opposed to plain sand or mud, are often particularly important, as they provide refuges against predation as well as a variety of different food resources." (Garpe 2008, p. 56).

S6 Maintenance of resilience

"A commonly used definition of ecological resilience is the extent to which ecosystems can absorb recurrent natural and human perturbations and continue to regenerate without slowly degrading or unexpectedly shifting to alternate states. This service is essential for maintained ecosystem function." (Garpe 2008, p. 64).

A.2 Regulating ecosystem services

R1 Climate and atmospheric regulation

"Chemical composition of the atmosphere and ocean is maintained through a series of biogeochemical processes. The marine environment and its living organisms are involved in the regulation of oxygen, ozone and dimenthyl sulphide, as well as in the exchange and regulation of carbon. In other words, the climate regulation taking place in the marine environment provides oxygen for breathing and slows down global warming." (Garpe 2008, p. 67).

R2 Sediment retention

"Sediment retention and the related mitigation of disturbances refer to ecosystems' natural way, by means of vegetation, to stabilize and retain sediments, thus mitigating coastal erosion. Along coastlines, winds, waves, currents and sediments interact continuously. These dynamic interactions govern the appearance of beaches and sandy shallow sea floors. If more material is transported to the coast than is extracted, sand will accumulate. If the reverse is true, and sand, gravel and rocks are transported from the beach without being replaces, the beach is subject to erosion. Meanwhile the presence of structural vegetation stabilizes and collects sediments." (Garpe 2008, p. 75).

R3 Mitigation of eutrophication

"Although primary production is a prerequisite for all production in the sea, nutrient input and consequently production can be excessive, at least for societal and economic aspects of ecosystem services. The condition known as eutrophication causes increased frequency and magnitudes of algal blooms, increase of filamentous algal mats, reduced water transparency, hypoxic sea floors, habitat loss and impaired recruitment success of commercial fish."

"The ecosystem service mitigation of eutrophication, or removal of excess nitrogen (N) and phosphorus (P) from the sea occurs mainly through the following processes (...): 1) The uptake of nutrients by marine organisms and subsequent harvesting of these organisms (particularly filter feeders which are direct consumers of phytoplankton), 2) Denitrification or the conversion of biologically available nitrogen to atmospheric nitrogen (N_2) by bacteria under hypoxic conditions, 3) Anaerobic removal of nitrogen including anaerobic nitrification and anaerobic oxidation." (Garpe 2008, p. 78).

R4 Biological regulation

"The wide definition of biological regulation refers to the situation where one organism regulates the abundance of another organism, typically by trophic interaction (one species feeding on another). In an ecosystem service perspective, the regulation of pests, pathogens and detrimental processes is directly or indirectly beneficial to society." (Garpe 2008, p. 84).

R5 Regulation of hazardous substances

"The marine environment holds the following critical functions with respect to toxic substances and societal waste: a) breaking down (bacteria), b) storing (most organisms) and c) burying (sediments) (...) It should be stressed that natural control of hazardous substances is not a service which in its own can take care of current waste loads or decontaminate all the toxic material we release." (Garpe 2008, p. 86).

A.3 Provisioning ecosystem services

P1 Provision of food fit for human consumption

"Non-toxic fish, shellfish and potentially also algae can be used for human consumption. Provision may be the result of harvest (commercial or subsistence) or farming. Not only does the provision of food benefit human nutrition, it also as creates employment and economic benefits." (Garpe 2008, p. 90).

P2 Provision of inedible goods

"The ecosystem service in question refers to the provision of a number of marine products. A significant proportion of fish catches are converted to fish meal and used for fodder (...) The extraction of sand, gravel and rocks for landfill, construction, beach nourishment and glass production is yet another example of inedible good originating from the marine environment. Finally, the extraction of oil products from the sea floor is considered." (Garpe 2008, p. 108).

P3 Provision of genetic resources

"Genetic resources are defined as the 'genetic material of actual or potential value'. Genetic material, in turn, is defined as 'any material of plant, animal, microbial, or other origin containing functional units of heredity (...) Already, genetic manipulation has improved production, resistance, taste and adaptation in a variety of commercially important terrestrial plants and animals. In contrary, the use of marine genetic resources is so far limited. Nonetheless, its potential may be considerate and for example, genetic resources may be needed to help meet the world's growing demand for fish." (Garpe 2008, p. 113).

P4 Provision of marine resources for the pharmaceutical, chemical and biotechnological industry

"This ecosystem service includes all pharmaceutical, chemical and biotechnical use of marine resources that we have, or may have, today and in the future." (Garpe 2008, p. 114).

P5 Provision of ornamental resources

"The provision of ornamental resources refers to the provision of marine products for the purpose of decoration or handicraft. Examples of products include shells, amber, driftwood and aquarium fish." (Garpe 2008, p. 121).

P6 Provision of energy

"Provision of energy refers to the acquisition of energy directly from the marine environment, for example by using water or tidal power. Offshore wind power, oil extracted from marine sediments and biofuel derived from marine resources are not included in this particular service." (Garpe 2008, p. 124).

P7 Provision of space and waterways

"Provision of space and waterways refers to the use of the sea surface as medium for transport (shipping), as site for energy provision (offshore wind parks) as well as for other types of construction (e.g. harbours, bridges, artificial islands). Within this service, the use of sea water for industrial purposes is included." (Garpe 2008, p. 126).

A.4 Cultural ecosystem services

C1 Enjoyment of recreational activities

"Enjoyment of recreational activities refers to economic and societal values of activities carried out in the marine environment such as sport fishing, boating, diving, swimming and bird watching. The service further includes the use of coastal and marine environments to promote and sustain national and international tourism." (Garpe 2008, p. 134).

C2 Enjoyment of scenery

"Enjoyment of scenery refers to aesthetic values of benefits to individual humans and society. This service includes the appreciation of beauty and silence." (Garpe 2008, p. 142).

C3 Contribution to science and education

"The existence of a varied marine life and a rich coastal environment is likely to stimulate various activities such as school excursions, the establishment of museums and aquaria, but also scientific research. Aspects of the marine coastal environment can also motivate the general public to engage in voluntary work, thereby raising environmental awareness. Furthermore, the marine environment provides historical records of environmental change, environmental indicators and early warnings of change." (Garpe 2008, p. 146).

C4 Maintenance of cultural heritage

"Maintenance of cultural heritage refers to the use of the marine and coastal environment for spiritual, sanatory or historical purposes." (Garpe 2008, p. 151).

C5 Inspiration for art and advertisement

"Inspiration from the coastal and marine environment and maritime activity has given rise to numerous art works including books, films, paintings, folklore, architecture as well as advertisement." (Garpe 2008, p. 156).

C6 The legacy of the sea

"The legacy of nature is a non-use benefit. The service refers to an appreciation of nature for ethical reasons (existence value), which is often accompanied by a willingness to preserve the intrinsic value of nature for future generations (bequest value). In this context, the legacy of nature is replaced by the legacy of the sea, referring to all aspects of the coastal and marine environment." (Garpe 2008, p. 159).

Appendix B: Policy abbreviations

AFS	Anti-Fouling System Convention
Agenda 21	United Nations Conference on Environment and Development Agenda on sustainable development
BSAP	Baltic Sea Action Plan
BSPA	Baltic Sea Protected Area
Bunker	International Treaty on Civil Liability for Bunker Oil Pollution Damage, 2001
BWM	Ballast Water Management Convention
CBD	Convention on Biological Diversity
CFP	Common Fishery Policy
CLC	The International Convention on Civil Liability for Oil Pollution Damage, 1992
COLREG	Convention on the International Regulations for Preventing Collisions at Sea
ELD	Environmental Liability Directive of the EU
ESPOO	ESPOO Convention on the environmental impact of development activities (UN's Economic Commission for Europe)
ETS	EU Emissions Trading System
EU Dir. 2005/33	EU Directive on the sulphur content of marine fuels
EU Dir. 1999/32	Earlier EU Directive on the sulphur content of marine fuels
EU Dir. 2000:59	EU Directive port reception facilities for ship-generated waste and cargo residues
EU Dir. 2004/12	EU Directive on packaging and packaging waste
EU Dir. 94/25	EU Directive on harmonised requirements for recreational craft
EU DSD	EU’s Dangerous Substances Directive
EU PRD	EU's Port Reception Directive
FAO Code	Food and Agricultural Organization's Code of Conduct for Responsible Fisheries
HELCOM	Helsinki Commission
IMO	International Maritime Organization
Intervention Convention	International Convention Relating To Intervention On The High Seas In Cases Of Oil Pollution Casualties Act, 1987
IOPC	The International Oil Pollution Compensation Funds (IOPC Funds) are three intergovernmental organisations (the 1971 Fund, the 1992 Fund and the Supplementary Fund) which provide compensation for oil pollution damage resulting from spills of persistent oil from tankers.
LC 1972	London Convention on oil spill pollution
MARPOL	International Convention for the Prevention of Pollution from Ship
MB	Miljöbalken (Swedish Environmental Code), SFS 1998:808
MSFD	Marine Strategy Framework Directive
NFS 2006:7	Swedish Environmental Protection Agency’s guidance on connection of small-scale private sewers (Naturvårdsverkets allmänna råd om små avloppsanläggningar)
OPRC	International Convention on Oil Pollution on Preparedness, Response and Co-operation 1990
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
Paris MOU	EU’s Dangerous Substances Directive
SFS	Svensk författningssamling
SFS 1973:1149	Swedish law on jointly-owned private sewer facilities for holiday homes (Anläggningslagen)
SFS 1980:789	Swedish law of measures against pollution from ships (revised) (Förordning om åtgärder mot förorening från fartyg)

SFS 1980:424	Swedish law of measures against pollution from ships (Lag om åtgärder mot förorening från fartyg)
SFS 1996:18	Swedish law on safety and environmental rules for recreational boats (Lag om vissa säkerhets- och miljökrav på fritidsbåtar)
SFS 1998:808	See MB
SFS 1998:899	Swedish regulation on permissions related to private sewers (Förordningen om miljöfarlig verksamhet och hälsoskydd)
SFS 2006:12	Swedish law on public water services (Lagen om allmänna vattentjänster)
SFS 2010:743	Swedish law on change in the law of sulphurous fuels (Förordning om ändring i förordningen (1998:946) om svavelhaltigt bränsle)
SFS 2010:900	Swedish Planning and Building Act (Plan- och bygglagen)
SJÖFS 2001:12	Swedish Maritime Administration's guidance on reception for waste from ships (Sjöfartsverkets föreskrifter och allmänna råd om mottagning av avfall från fartyg)
SJÖFS 2005:4	Swedish Maritime Administration's law on safety and environmental rules for recreational boats (Sjöfartsverkets föreskrifter om ändring i Sjöfartsverkets föreskrifter (SJÖFS 2004:16) om vissa säkerhets- och miljökrav på fritidsbåtar)
SJÖFS 2008:5	Swedish Maritime Administration's law on fairway charges (Sjöfartsverkets föreskrifter om farledsavgift)
SOLAS	Convention of Safety of Life at Sea
SRS	Ship Reporting system
STCW	The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978
TAC	Total Allowable Catch
TSFS 2010:96	Swedish Transport Agency's guidance on pollution from ships (Transportstyrelsens föreskrifter och allmänna råd om åtgärder mot förorening från fartyg)
UNCLOS	United Nation Convention on the Law of the Sea
UNEP-GPA	United National Environment Program - Global Action Program
VMS	Vessel Monitoring System
WFD	Water Framework Directive