The cost of degradation of the Dutch North Sea environment

A study into the costs of avoiding degradation and the applicability of the Ecosystem Services approach

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Dit rapport geeft inzicht in de huidige (2015) jaarlijkse kosten die uitgegeven worden om aantasting van het mariene milieu van het Nederlandse deel van de Noordzee te voorkomen of te minimaliseren. Daarnaast wordt inzicht gegeven in de potentiële toepassing van de ecosysteembenadering als methode om te berekenen wat de waarde is van extra ecosysteemdiensten bij een scenario waarbij de Goede Milieutoestand (GMT) gerealiseerd is ten opzichte van een Business as Usual scenario. De jaarlijkse totale kosten van maatregelen die aantasting van het Nederlandse Noordzeemilieu voorkomen, zijn voor 2015 berekend op ten minste € 0,5-1,6 mld. Voor wat betreft de toepassing van de ecosysteemdienstenbenadering is geconcludeerd dat de methodologie en empirische toepassing nog niet ontwikkeld genoeg zijn om binnen de context van de Kaderrichtlijn Mariene Strategie toe te passen.

This report provides an insight into the cost of degradation of the marine environment of the Dutch part of the North Sea by calculating the annual current (2015) costs of measures that avoid or minimise degradation. In addition to this, insight is provided into the potential applicability of the ecosystem services approach to calculate ecosystem benefits gained when Good Environmental Status is reached, in comparison to a Business as Usual scenario. The total costs of measures that avoid degradation of the Dutch North Sea environment have been calculated to be at least €0.5bn per year, with a maximum estimate of €1.6bn per year. In terms of the applicability of the ecosystem services approach concept, it is concluded that the methodology and empirical application are not mature enough yet to be applied within the context of the Marine Strategy Framework Directive.

Key words: Marine Strategy Framework Directive, Costs, North Sea, Ecosystem Approach

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Contents

Summary

The aim of this report is to provide an overview of the cost of degradation of the Dutch North Sea environment. This is done by calculating the annual current (2015) costs of measures that avoid (reduce or minimise) degradation. In addition to this, insight is provided into the potential applicability of the ecosystem services approach methodology to calculate ecosystem benefits gained when Good Environmental Status is reached, in comparison to a Business as Usual scenario.

S.1 Annual costs of measures that avoid degradation

Given the assumptions used the total costs of measures that avoid degradation of the Dutch North Sea environment (and which contribute to reaching Good Environmental Status) have been calculated to be at least €0.5bn per year, with a maximum estimate of €1.6bn per year (Table S.1).

Table S.1 *The estimate of the minimum total annual current (2015) costs of measures that avoid degradation of the Dutch part of the North Sea environment, €m*

Activity type	Annual cost:
The physical restructuring of rivers, coastline or seabed	62-64
The extraction of non- living resources	7.4
The production of energy	65.4-176.6
The extraction of living resources	29.1-32
The cultivation of living resources	9.1-58.8
Transport	€56.2-63m
Urban and industrial uses	175-1,131
Tourism and leisure	4.4-6
Security and defense	0.3
Government	35
Other activities and measures	8.9-9.8
Total cost estimate	**>453-1,584**

The categorisation used in Table S.1 is based on uses and human activities in or affecting the marine environment. This categorisation was proposed by the Marine Strategy Regulatory Committee in November 2016 (European Commission, 2017).

A relatively large share of the total costs falls into the category ‘urban and industrial uses’ (€175-1.131m). Measures within this category are related to several (high cost) land-based measures, such as sewage treatment. These measures mainly have an effect on inland water quality, but partially also on the North Sea environment (an example is treated sewage water that enters the sea through rivers). This is the reason why for these types of measures, only a proportion of the costs has been considered. Because the exact share of these effects on the Dutch North Sea environment is not known, a minimum of 5% and a maximum of 30% was chosen to have an effect (based on expert judgement). Most of the other categories have a much narrower cost range estimate. The relatively high costs of the category ‘urban and industrial uses’ in combination with the wide cost range applied also explains the relatively large minimum-maximum range in the total cost estimate.

The costs calculated in this study represent the lower bound of the actual cost of degradation. There are two reasons for this. First, this approach only calculates the cost of degradation to the extent that society is currently spending money to avoid degradation (and in this way contributing to Good Environmental Status/GES). The costs of potential additional (= not current) measures to fully avoid

degradation are not taken into account. Second, for some measures, information about the costs was not available and further study is warranted.

S.2 Application of the ecosystem services approach

Within the EU, the ecosystem services approach is increasingly being proposed as an approach to calculate the cost of degradation by looking into the potential ecosystem benefits gained if GES is reached. The concept is appealing, because it offers a methodology that allows quantification and links the ecological concepts with those of economists. However, in this report it is concluded that the ESS concept, methodology and empirical application are not developed enough yet to be applied within the context of the Marine Strategy Framework Directive:

a. The main problem in the quantification of the value of ecosystem services provided in GES is the lack of data on GES descriptors/criteria and on the value of the different ecosystems for the beneficiaries, and the limited understanding of the functioning of the marine ecosystem.
b. An extra complicating factor is that monetary valuation of non-market goods is not widely accepted by policy makers in the Netherlands.
c. The provision of ecosystem services depends on a lot of biotic, physical and economic processes. The relevant relations are not sufficiently known to quantify the changes in ecosystem services.

S.3 Method

Calculating the cost of degradation of the marine environment is an obligation for EU member states under the Marine Strategy Framework Directive. However, the calculation method is not a standardised type of economic analysis. Therefore, the European Working Group on Economic and Social Analyses (WG ESA) developed a ‘guidance document’ which describes a number of approaches to calculate the cost of degradation of the marine environment (EU com, 2011).

The Netherlands has chosen to use the approach where the current annual (2015) costs of measures that avoid (reduce or minimise) degradation are calculated, but is also interested in the possibility of applying the ecosystem services approach as a methodology to calculate the cost of degradation.

Within this context, Wageningen Economic Research was asked to 1) calculate the costs of measures that avoid (reduce or minimise) degradation and 2) to provide insight into the potential application of the ecosystem services approach as a methodology to calculate ecosystem benefits gained when Good Environmental Status is reached, in comparison to a Business as Usual scenario:

1. The first approach is to calculate the annual costs of current measures that avoid degradation of the marine environment. This approach is described in Chapter 4.3 of the guidance document of WG ESA (EU com, 2011) as the cost-based approach and has also been applied in the 2011 LEI report (Walker et al., 2011).

   The core of this approach is a quantitative analysis of the (financial) costs that are currently annually spent on measures that are taken to realise and maintain the current state of the marine environment. This method can only calculate the cost of degradation to the extent that society is currently spending money to avoid degradation (public and private spending). Therefore, these costs can be considered to be a lower bound of the cost degradation.

   The focus in the analysis will be on the costs of measures mentioned in the Dutch Programme of Measures for the MSFD (Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, 2015). As such, the costs calculated in this approach are also the costs that contribute to reaching Good Environmental Status (GES). Where information is available on costs for other relevant measures not mentioned in the MSFD Programme of Measures, these will also be included in the calculation.

2. The second approach to calculate the cost of degradation is based on the Ecosystem Services Approach (ESS). The Ecosystem Services Approach is mentioned in Section 4.1 of the guidance document of WG ESA. This approach provides information on the value of the additional ecosystem goods and services that would be provided if Good Environmental Status would be reached. This value is then compared to value in the Business as Usual scenario. By calculating the difference between these two values, insight is gained into the value of forgone ecosystem services benefits to be gained if/when GES is reached and equals the cost of degradation. In this report, several options to calculate the ESS are discussed and elaborated upon. Based on this, the preferred option is presented.

Data for the calculation of the current costs were collected through literature research, contact with experts, and through various websites. Experts were consulted for further sources of information that were not available through the internet and available literature, as well as their expert opinion regarding assumptions which were made to calculate costs. A list of consulted experts is available in Appendix 1.

Samenvatting

S.1 De jaarlijkse kosten van maatregelen om aantasting van het Noordzeemilieu te voorkomen

Dit rapport geeft inzicht in de kosten die verbonden zijn aan de aantasting van het mariene milieu van het Nederlandse deel van de Noordzee. Hierbij worden de kosten berekend van de huidige (2015) jaarlijkse kosten die uitgegeven worden om aantasting van het mariene milieu in het Nederlandse deel van de Noordzee te voorkomen (reduceren of minimaliseren). Daarnaast wordt inzicht gegeven in de toepassing van de ecosysteembenadering als methode om de potentiële waarde van ecosysteemdiensten te berekenen die gerealiseerd kan worden als de Goede Milieutoestand (GMT) bereikt wordt, vergeleken met een Business as Usual-scenario.

Met inachtneming van de aannames die in dit rapport gedaan zijn en het feit dat informatie over de kosten van enkele maatregelen ontbreken, zijn de jaarlijkse totale kosten van maatregelen die aantasting van het Nederlandse Noordzeemilieu voorkomen (en die bijdragen aan het realiseren van de Goede Milieustatus) voor 2015 berekend op minimaal € 0,5-1,6 mld. (tabel S.2).

Tabel S.2 *De inschatting van het minimum aan totale jaarlijkse huidige (2015) kosten van maatregelen die genomen worden om aantasting van het Nederlandse deel van de Noordzee te voorkomen*

Type activiteit	Jaarlijkse kosten, x € mln.
Het fysiek herstructureren van rivieren, kustlijnen of zeebodems	62-64
De extractie van niet-levende hulpbronnen	7,4
Energieproductie	65,4-176,6
De extractie van levende hulpbronnen	29,1-32
Het kweken van levende hulpbronnen	9,1-58,8
Transport	€56.2-63m
Stedelijke en industriële activiteiten	175-1.131
Toerisme en vrije tijd	4,4-6
Veiligheid en defensie	0,3
Overheid	35
Overige activiteiten en maatregelen	8,9-9,8
Totale kostenschatting	**>453-1,584**

De categorisering die toegepast wordt in tabel S.2 is gebaseerd op het gebruik en menselijke activiteiten die op zee plaatsvinden of daar invloed hebben. Dit is een categorisering voorgesteld door Marine Strategy Regulatory Committee in November 2016 (European Commission, 2017).

Een relatief groot gedeelte van deze kosten zitten in de categorie ‘stedelijke en industriële activiteiten’ (€175-1.131 mln.). In deze post zitten maatregelen die betrekking hebben op land-gerelateerde maatregelen (met hoge kosten) zoals rioolwaterzuivering. Deze maatregelen hebben grotendeels effect op de waterkwaliteit op land maar gedeeltelijk ook op het Noordzeemilieu (denk bijvoorbeeld aan gezuiverd water dat via de rivieren in zee terechtkomt). Daarom is voor dit type maatregelen een gedeelte van de kosten in de berekening meegenomen. Omdat het precieze percentage van deze effecten op het milieu van het Nederlandse deel van de Noordzee niet bekend is, is gerekend met een bandbreedte tussen de 5% en 30% (gebaseerd op expert judgement). In de meeste andere categorieën is deze bandbreedte een stuk smaller. De relatief hoge kosten van de categorie ‘stedelijke en industriële activiteiten' in combinatie met de toegepaste bandbreedte verklaart grotendeels ook de relatief grote bandbreedte in de totale kosteninschatting.

De kosten van de huidige maatregelen die genoemd staan in tabel S.2 vormen de ondergrens van alle aan de aantasting van het Noordzeemilieu verbonden kosten. Hiervoor zijn twee redenen: ten eerste wordt met deze benadering uitsluitend rekening gehouden met de jaarlijkse kosten die de maatschappij uitgeeft om aantasting te voorkomen (en op deze manier bij te dragen aan de realisatie van de Goede Milieutoestand/GMT). De kosten van hypothetische additionele maatregelen om aantasting volledig te voorkomen worden niet in deze berekening meegenomen. Ten tweede is er voor sommige huidige maatregelen geen informatie beschikbaar over de kosten. Daarmee dienen de kosten die met deze methode berekend worden beschouwd te worden als een ondergrens van de werkelijke kosten die verbonden zijn aan de aantasting van het mariene milieu van het Nederlandse deel van de Noordzee.

S.2 Toepassing van de ecosysteemdienstenbenadering

Binnen de EU wordt er steeds vaker gesproken over het toepassen van de ecosysteemdienstenbenadering bij het bepalen van kosten die verbonden zijn aan de aantasting van het mariene milieu door de potentiële opbrengsten van ecosysteemdiensten te berekenen bij het realiseren van GES. Dit concept is aantrekkelijk omdat het een methodologie is die kwantificering mogelijk maakt en ecologische en economische aspecten combineert. Echter, in dit rapport wordt geconcludeerd dat het ecosysteemdienstenconcept, de methodologie en empirische toepassing nog niet ontwikkeld genoeg zijn om toe te passen binnen de context van de Kaderrichtlijn Mariene Strategie. De belangrijkste redenen voor deze conclusie zijn als volgt:

a. Het belangrijkste probleem in het kwantificeren van de waarde van extra ecosysteemdiensten die worden geproduceerd in de Goede Ecologische Toestand (GET) is het gebrek aan data over de GET-descriptoren en -criteria, over de waarde van de verschillende ecosysteemdiensten voor gebruikers en een gebrekkige kennis van het functioneren van het mariene ecosysteem.
b. Een extra complicerende factor is dat de monetaire waardering van niet-marktgoederen nog niet breed geaccepteerd is door beleidsmakers in Nederland
c. De productie van ecosysteemdiensten hangt af van veel biotische, fysieke en economische processen. De relevante relaties daartussen zijn nog niet voldoende bekend om veranderingen in ecosysteemdiensten te kunnen kwantificeren.

S.3 Methode

Het berekenen van de kosten die verbonden zijn aan de aantasting van het mariene milieu is een verplichting vanuit de Kaderrichtlijn Mariene Strategie. Hiervoor is echter geen gestandaardiseerde economische analyse. Dit is de reden dat de European Working Group on Economic and Social Analyses (WG ESA) een 'guidance document' heeft opgesteld, waarin een aantal toepasbare benaderingen nader omschreven worden (EU com, 2011).

Nederland heeft hierbij gekozen voor de benadering waarbij de jaarlijkse huidige financiële kosten van maatregelen die aantasting van het mariene milieu voorkomen berekend worden, maar is ook geïnteresseerd in de mogelijkheid om de ecosysteembenadering toe te passen. Wageningen Economic Research is daarom gevraagd om 1) de kosten van maatregelen die aantasting voorkomen uit te rekenen en 2) inzicht te geven in de potentiële toepassing van de ecosysteembenadering als methode om de potentiële waarde van ecosysteemdiensten te berekenen die gerealiseerd kan worden als de Goede Milieutoestand (GMT) bereikt wordt, vergeleken met een Business as Usual-scenario:

1. De eerste benadering is het berekenen van de kosten van maatregelen die aantasting van het mariene milieu voorkomen. Deze benadering wordt in hoofdstuk 4.3 van het guidance document van de WG ESA (EU com, 2011) omschreven en heet daar de 'cost-based approach'. Deze benadering is ook toegepast in het LEI-rapport uit 2011 (Walker et al., 2011).

De kern van deze benadering is een kwantitatieve analyse van de huidige jaarlijkse kosten die uitgegeven worden om de huidige toestand van het mariene milieu te realiseren en behouden. Deze methode kan uitsluitend de kosten berekenen die verbonden zijn aan de aantasting van het mariene milieu van het Nederlandse deel van de Noordzee voor zover de maatschappij (overheids- en private) kosten uitgeeft om aantasting te voorkomen. Daarmee kunnen deze kosten beschouwd worden als de ondergrens van de kosten verbonden aan de aantasting van het Noordzeemilieu.

De focus in de analyse ligt op de maatregelen die in het Nederlandse KRM Programma van Maatregelen genoemd staan (Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, 2015). Daarmee zijn de kosten die met deze benadering uitgerekend worden ook de kosten die bijdragen aan het realiseren van de Goede Milieutoestand (GMT). Indien er informatie beschikbaar is over relevante maatregelen die niet in het programma van maatregelen benoemd staan, dan worden die ook in de analyse meegenomen.

2. De tweede benadering is gebaseerd op de *ecosysteemdienstenbenadering*. In deze benadering wordt de waarde van ecosysteemdiensten berekend die gerealiseerd kan worden als de Goede Milieutoestand (GMT) bereikt wordt. Deze waarde wordt vervolgens vergeleken met die van een Business as Usual scenario. Door het verschil tussen deze twee waardes te berekenen ontstaat inzicht in de waarde van ecosysteemdiensten die gerealiseerd zouden kunnen worden bij het behalen van een Goede Milieutoestand. Deze waarde staat gelijk aan de kosten die verbonden zijn aan de aantasting van het mariene milieu. De ecosysteemdienstenbenadering wordt omschreven in hoofdstuk 4.1 van het guidance document van de WG ESA. In dit rapport worden verschillende manieren beschreven en bediscussieerd om deze te berekenen. Op basis van deze analyse wordt de voorkeursoptie gepresenteerd.

De gegevens die gebruikt zijn om deze kosten te berekenen zijn verkregen via literatuuronderzoek, contact met experts en via verschillende websites. Experts zijn benaderd in het geval er onvoldoende informatie beschikbaar was via literatuur of het internet, of als hun expert opinion nodig was om bepaalde kosten in te schatten. Een lijst met geraadpleegde experts staat in Appendix 1 van dit rapport.

1 Introduction

1.1 Background

The aim of the Marine Strategy Framework Directive (MSFD) is to more effectively protect the marine environment across Europe. It aims to achieve Good Environmental Status (GES) of the EU's marine waters by 2020 and to protect the resource base upon which marine-related economic and social activities depend. GES means that the overall state of the environment in marine waters provides ecologically diverse and dynamic oceans and seas which are healthy and productive.

The MSFD requires that the use of the marine environment must be kept at a sustainable level that safeguards potential uses and activities by current and future generations. This means that the structure, functions and processes of marine ecosystems have to be fully considered, marine species and habitats must be protected and human-induced decline of biodiversity prevented (European Parliament, Council, 2008).

Each EU Member State - cooperating with other Member States and non-EU countries within a marine region - is required to develop strategies for their marine waters. The marine strategies to be developed by each Member State must contain a detailed Initial Assessment of the state of the environment, including (amongst others) the cost of degradation of the marine environment (European Parliament, Council, 2008).

The European Working Group on Social and Economic Analysis (WG ESA) presented several approaches to assess the state of the marine environment in their 'guidance document', which was published in 2011 (EU com, 2011).

One of these approaches is the 'cost-based approach' (mentioned in Section 4.3 in the guidance document), where the costs of measures that avoid (reduce or minimise) degradation are calculated. During the first and (current) second round of the Initial Assessment, the Netherlands has chosen to apply this approach to assess the state of the marine environment. The first study into the cost of degradation, was carried out by Wageningen Economic Research (formerly known as LEI) (Walker et al., 2011).

Another approach, mentioned in Section 4.1 of the guidance document, to calculate the cost of degradation is the 'Ecosystem services approach'. In this approach, the potential value of ecosystem services of the Good Environmental Status is calculated. This value is then compared to value in the Business as Usual scenario. By calculating the difference between these two values, insight is gained into the value of forgone ecosystem services benefits to be gained if/when GES is reached. This approach has been applied by five other EU countries during the first phase of the implementation of the MSFD in 2010/2011.

In 2018, an update of the Initial Assessment, including the 'cost of degradation', needs to be completed and offered to the European Commission by each Member State. Therefore, an update and elaboration on the earlier study that has been carried out in 2011 is needed. The Netherlands has chosen to apply the approach where the current annual (2015) but is also interested in the possibility of applying the ecosystem services approach as a methodology to calculate these costs.

Rijkswaterstaat Water, Verkeer & Leefomgeving (WVL) has asked Wageningen Economic Research to carry out a study into the cost of degradation of the Dutch part of the North Sea environment by 1) calculating the annual costs of measures that avoid degradation and 2) by providing insight into the potential application of the ecosystem services approach as a methodology to calculate the cost of degradation.

1.2 Aim

The aim of this report is to provide an overview of the cost of degradation of the Dutch North Sea environment. This is done by calculating the annual current (2015) costs of measures that avoid (reduce or minimise) degradation. Next to this, insight is provided into the potential applicability of the ecosystem services approach methodology to calculate ecosystem benefits gained when Good Environmental Status is reached:

1. In the first part of the study (Chapter 2), the aim is to provide insight into the cost of degradation by applying the approach that calculates the annual current costs of measures that avoid (reduce or minimise) environmental degradation. 2015 has been chosen as the current year, as this is the most recent year where most of the necessary data are available.

   This approach only calculates the cost of degradation to the extent that society is currently spending money to avoid degradation (and in this way contributing to Good Environmental Status/GES). Potential additional (= not current) measures on top of those to reach reach a ‘pristine’ status are not taken into account. Therefore, the total costs calculated with this approach must be considered as a lower bound for this willingness to pay.

   An important source of information used to delineate what measures should be considered as ‘current’ in this study is the Dutch Programme of Measures for the MSFD (Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, 2015). This programme contains a list of measures that are currently taken or will be taken in the future to reach the targets set for Good Environmental Status. Where information is available on costs for other relevant measures not mentioned in the MSFD Programme of Measures, these will also be included in the calculation.

2. In the second part of the study (chapter 3), the Ecosystem Services Approach will be discussed as an alternative approach to calculate degradation of the marine environment. The Ecosystem Services Approach is mentioned in Section 4.1 of the guidance document of WG ESA (EU com, 2011). This approach provides information on the value of the additional ecosystem goods and services that would be provided if the GES for the Dutch part of the North Sea would be achieved, compared to the ‘Business as Usual’ scenario.

   Based on the WG ESA guidance document (EU com, 2011), recent literature on ecosystem services & ecosystem based management and the definition of GES descriptors, several options to calculate the ESS are elaborated upon. Based on this, the preferred option is presented.

Figure 1.1 shows the relationship between these two approaches. On the left-hand side is an overview of the costs which is relevant to the first part of this report (the cost-based approach), On the right-hand side an overview which is relevant for the second part of this report (the ecosystem services approach). The value of the marine environment calculated using the ecosystem services approach provides insight into the benefits of reaching Good Environmental Status (GES).

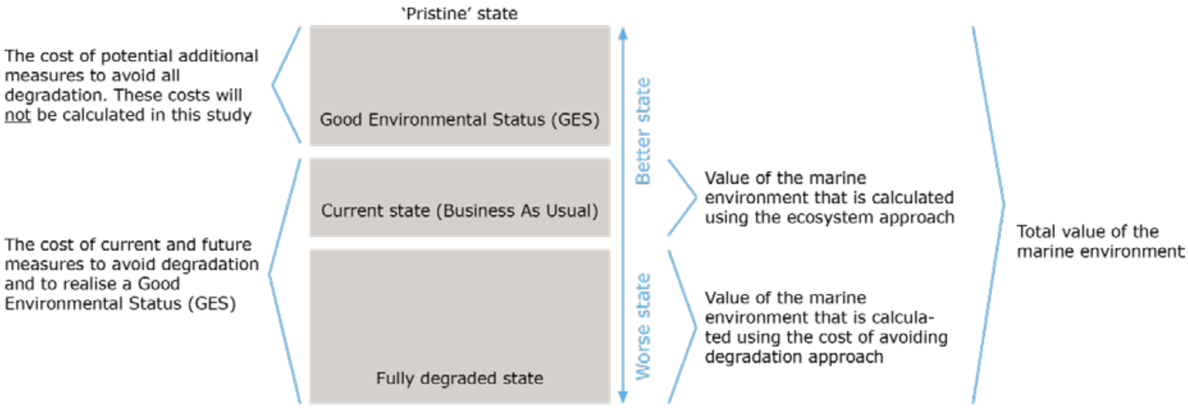

Figure 1.1 *The relationship between the costs of avoiding degradation and the ecosystem services approach*

2 The costs of avoiding degradation

2.1 Introduction

In this chapter, both the methodology to calculate the costs of measures that avoid degradation will be discussed. The focus will be on the measures mentioned in the Dutch Programme of Measures for the MSFD (Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, 2015). Where information is available on costs for other relevant measures not mentioned in the MSFD Programme of Measures, these will also be included in the analysis.

2.2 Methodology and approach

As mentioned in Chapter 1, the first approach to calculate the cost of degradation (the ecosystem services approach being the second one) is to calculate the cost of *avoiding* degradation. This approach and the underlying methodology applied in this study has also been applied and described in the 2011 study and is in line with the cost-based approach described in the WG ESA Guidance document (EU com, 2011).

The calculation of the cost of avoiding degradation does not estimate the losses in profit and environmental value directly. Instead, it considers the costs of measures aimed at preventing further degradation to the marine environment and uses these to make inferences about how much the current state of the marine environment is valued by society. The reason supporting this is that through the decision-making process, society (assuming decision makers accurately represent society) reveals (part of) the value it places on the marine environment (see e.g. Hueting, 1974).

In this way, this method can be seen as a ‘revealed preference’ approach. Revealed preference is a sub-field of environmental valuation, which studies the actions of people to derive their values and preferences. The other subfield is ‘stated preference’. The latter studies use questionnaires to derive values and preferences. There are arguments saying that revealed preferences calculations are more reliable than stated preference calculations. This point is often based around the fact that looking at what people actually do is more meaningful than asking them hypothetical questions. Regardless of which method is used, in reality ‘the best’, revealed preference studies are certainly strong according to this argument and are perceived, by some, to usually produce more reliable estimates.

Another point to note with the theory behind this method is that it is important to consider what is being ‘revealed’. In this case, only the willingness to pay for existing measures to prevent further degradation are revealed. Despite the money that is currently spent on avoiding degradation, due to human activities, certain degradation still exists (e.g. marine litter, underwater noise, pollution, etc.).

A final note is that this method can only calculate the cost of degradation to the extent that society is currently spending money to avoid degradation (including those that contribute to reaching Good Environmental Status/GES). Potential or hypothetical additional measures to reach an even better status are not taken into account. The current measures taken to avoid degradation therefore represent the ‘certain’ part (or: lower bound) of the actual cost of degradation. The lower bound calculated in this study should also be considered to be a ‘lower bound of the lower bound’, since data on current costs are not always available or measures that have the effect of avoiding degradation might not have been identified.

In the methodology outlined above, there are many different types of costs of measures of different magnitudes, which occur over different time scales, that need to be considered. At the most basic level, the costs need to be considered in terms of:

1. Whether they relate to land or sea (Dutch part of the North Sea or wider)
2. Who is paying for the measure
3. The time period over which they are paid
4. Where ordinary costs end and additional costs due to MSFD begin.

The following subsections describe how these issues have been dealt with in this report.

2.2.1 Sea-based or land-based costs

This study covers both land-based and sea-based costs. The sea-based costs require consideration of the variety of sectors that operate on the Dutch part of the North Sea (EEZ). These include, amongst others, fishing, oil and gas extraction, sand mining, shipping and wind farms. Examples of costs of measures taken by such sea-based activities are the costs of complying with regulations for shipping such as non-toxic anti-fouling paint, marine litter and safe and clean shipping.

Land-based costs are important because land-based activities can have significant effects on the Dutch part of the North Sea environment, most of them in an indirect way. As such, the costs of ongoing measures such as those taken to maintain good inland water quality as well as the improvements occurring under the Water Framework Directive (WFD) are considered. Activities which occur inland include the activities in ports, agriculture, aquaculture and around rivers (i.e. litter clean-ups).

2.2.2 Costs to the private sector

Costs paid by the private sector need to be carefully considered. Costs to businesses are, in theory, represented as changes in profits (surplus) because this figure effectively represents the real costs to society (i.e. a loss in profit is a cost and an increase in profit is a benefit). While this is theoretically preferable, due to a lack of data, other figures are sometimes used if data are not available. For example, gear restrictions may increase a firm’s cost but the changes in fishing gear may also (positively or negatively) affect the yield (revenue). As such, the effect on profit is the best way to accurately show the costs of measures taken that reduce or minimise the impact of these activities on the marine environment.

During the data collection process, flexibility was required since changes in profits were not always easily available. Flexibility was maintained in order to acquire the most data with reasonable levels of accuracy, while understanding the limitations of the data.

Complications of private sector costs stem from the multinational use of the Dutch part of the North Sea and other areas of the oceans. They are also related to the multinational nature of businesses which use the North Sea. These facts complicate the process of isolating the costs which are incurred on the Netherlands. As such, assumptions are required to make this process manageable.

Costs to the private sector have to be related the Dutch part of the North Sea. A problem is that the Dutch part of the North Sea is used by companies based all over the world and by ships registered all over the world. Dutch vessels also operate both in the Dutch part of the North Sea and across the rest of the world’s oceans. Careful thought is required to decide how to deal with this fact.

Ideally, percentages can be used to quantify the proportion of costs allocated to the Dutch part of the North Sea. This relates to, for example, measures regarding shipping and fisheries. Clearly, the proportions differ between these two industries. The derivation of a percentage for fishing is shown in Section 2.7. For shipping, a percentage of 10% is used. This stems from Ecorys (2007) and is considered to be a suitable estimate for this report.

In addition to the spatial issues regarding allocating costs to the Dutch part of the North Sea, it is also important to consider where companies are based and who owns them. Ideally, only Dutch companies operating in the Dutch part of the North Sea will be counted. However, due to a lack of data, this is not always possible. Where non-Dutch companies are included in the calculations, this is made clear in the accompanying text to allow the evaluation of this effect on the results.

In parallel to the issue of ownership, it is worth remembering that many companies operating on the Dutch part of the North Sea have international ownership. Consider an oil rig run by a Dutch company in the Dutch part of the North Sea. The additional costs of environmental regulation are incurred by a Dutch company and as such there is a loss of profit for a Dutch company operating in the Dutch part of the North Sea. Shareholders own the business and are the ultimate recipients of profits. The shareholders of the Dutch company may well be based all around the globe.[1] It is definitely the case that the Dutch government will lose out on the tax on profits levied on the company, if they incur extra costs due to MSFD. In the case of Dutch companies operating in the North Sea, results will be obtained by counting all of the losses in profits which they incur due to environmental measures and legislation.

In addition, Dutch companies operating outside of the Dutch part of the North Sea will incur costs from the legislation imposed by other countries or by international legislation (such as IMO). This will have an impact on the profits of the Dutch companies. However, the key point is that, although it is not Dutch legislation that causes the effect on profit, the measures related to it will be considered in this analysis since they reduce or minimise the impact of these activities on the marine environment.

2.2.3 Costs to the public sector

The costs to the public sector come in several forms. Examples of these are the costs of subsidies to encourage the adoption of new fishing gear with less environmental impact, or the costs of measures that are taken inland to improve water quality (e.g. municipal wastewater treatment plants).

A very significant element of costs is simply the cost of running the sections of the government dealing with (the management of) the North Sea environment. Several sectors of government are involved, both concerning land-based and sea-based activities. The costs of running the government is estimated by multiplying the number of people involved and the costs per person. A useful unit to quantify this is the costs of a Full Time Equivalent (FTE). In addition, government spending on research, monitoring and other expenditures (such as sewage treatment) are estimated. In this report the cost of an FTE includes the cost of facilities and equipment as well as the salary for the employee. Similar to the earlier report in 2011, this report also uses the assumption that an FTE costs €100,000 per year.

2.2.4 Costs over time

In this report, *current* annual costs are the relevant numbers; 2015 is chosen as it is the most recent year of which data are available. In many cases, ongoing projects did not yet incur any costs in 2015, or had significantly different costs before and after 2015. For example a wind farm can take up to 7 years to get through the planning process. In such instances, costs are averaged over 7 years. Throughout the report different case-specific assumptions are made about the best way to deal with the time element. The basic principle is that current costs do not have to be incurred in 2015 per se, but must be incurred within a definable and relevant period which includes 2015.

Discounting is not used in this study. Discounting takes streams of annual values and turns them into a single number. This number is called a ‘present value of the stream of values’ or normally just ‘present value’. If the ‘definable and relevant period’ and discount of the annual costs over that period is used, then the present value tells us what the impact of the whole stream of values is in the present time. This does not reflect how much money is actually being spent in the year in question.

[1] This report will not analyse the ownership of companies to determine the degree to which they are actually ‘Dutch’.

2.2.5 Ordinary costs vs. additional costs due to MSFD

Another important issue is defining where ordinary costs of operating a business end, and where additional costs for measures that reduce or minimise environmental impact begin. Additional costs are attributed to those costs that have a positive effect or mitigate negative effects on the Dutch part of the North Sea environment. Isolating these additional costs is key to providing meaningful results. The definition, while constant in theory, varies between industries in practice. For example, normal regulations relating to rerouting of shipping lanes for safety reasons may not be regarded as costs incurred due to environmental concerns, although avoiding accidents will prevent potential pollution and marine environmental degradation. In the end, where measures may have a different main purpose than marine environmental concerns, but have the effect of reducing or minimising marine environmental impact, these costs will be counted as additional costs.

2.2.6 Types of measures and categorisation

In the following sections, the measures aimed at avoiding degradation of the Dutch part of the North Sea are discussed, including their costs. The focus will be on the measures mentioned in the Dutch Programme of Measures for the MSFD (Ministerie van Infrastructuur en Milieu, Ministerie van Economische Zaken, 2015). Where information is available on costs for other measures not mentioned in the MSFD Programme of Measures, this will also be included in the analysis.

The Dutch Programme of Measures for the MSFD contains a list of measures referenced to as category 1A, 1B, 2A or 2B measures, where category 1a refers to measures that have already been implemented, category 1b to those that have been set but not yet (fully) implemented, category 2a describes additional (i.e. stricter) measures that could be taken as an addition to 1a and 1b measures, and finally, category 2b refers to measures that are new and not related to any of the 1a, 1b or 2a measures.

In this study, the annual costs of *current MSFD measures (1A/1B)*, with 2015 as the reference year will be calculated. If information is available on *additional MSFD measures (2A, 2B)* mentioned in the Programme of Measures or *additional other measures (O)* not mentioned in the MSFD Programme of Measures, this will also be mentioned.

In this report, all measures are categorised in sections that are equal to the categorisation for uses and human activities in or affecting the marine environment, which were proposed by the Marine Strategy Regulatory Committee in November 2016 (European Commission, 2017). This categorisation consists the following uses and activities: the physical restructuring of rivers, coastline or seabed, the extraction of non- living resources, the production of energy, the extraction of living resources, the cultivation of living resources, transport, urban and industrial uses, tourism and leisure, security and defense, education and research and government.

2.3 Physical restructuring of rivers, coastline or seabed

This theme includes the following activities: land claim, canalisation and other watercourse modifications, coastal defence and flood protection, offshore structures (other than for oil/gas/renewables), restructuring of seabed morphology, including dredging and depositing of materials. In this section, the following measures will be described: processing of contaminated material, zoning and phasing of activities along the coast, and the partial opening of the Haringvliet locks. In 2015, no large scale hydrographic interventions (e.g. Maasvlakte II) have been made. As such, no costs are attributed to this type of measure for 2015.

The relocation of dredged material
Most of the larger Dutch ports are situated on the North Sea and the Rhine, Scheldt and Meuse estuaries (CBS, 2017). Deposition of marine and fluvial sediment occurs at these locations. This is most apparent in the port of Rotterdam. Marine sediments accumulate through tidal action mainly in

the western port areas, whereas the eastern port areas are mainly influenced by fluvial sediments, transported by the Rhine (Vellinga & Eisma, 2005).

These marine and fluvial sediments, if left undisturbed, pose a hazard to sea traffic and the accessibility of the ports. Therefore, about 30m m^3 of material is dredged every year from all Dutch seaports and seaways. In the port of Rotterdam alone, some 20m m^3 of sediment is dredged each year (Vellinga & Eisma, 2005). Most of the sediments to be dredged originate from the marine environment and only around half of the river sediment settles in the port. Heavy metals such as zinc and copper are commonly found in port sediments as well as Polycyclic Aromatic Hydrocarbons (PAHs) and Tributyltin (the toxic part of anti-foul paints which was previously applied to ship hulls).

The relocation of dredged material from harbour basins to the North Sea, which is the preferred and cheapest option for disposal, is regulated by a set of chemical criteria. This means that a certain part of the dredged material that would otherwise be disposed of at sea has to be disposed of in confined (land-based) sites (in the case of Rotterdam: the Slufter) to prevent degradation of the North Sea environment. Most of the dredged material (about 28m m^3 on an annual basis) is returned to the North Sea, but around 2m m3 of dredged material exceeds certain limits of heavy metals. The costs of processing the contaminated dredged material is estimated to be around €20 per m^3. The cost of relocating dredged material at sea are estimated to be around €5 per m^3. The annual additional costs for the 2m m^3 are therefore estimated to be around €30m (Walker et al., 2011).

Zoning and phasing of activities along the coast
The management plans for the Natura 2000 areas along the coast stipulate that the presence of nesting locations must be taken into account during coastal (beach) sand replenishment, maintenance on cables and pipelines, and beach management. Zoning and phasing should help to improve the quality of the habitat for birds and seabed habitats. The costs of this measure were budgeted for 2016 and estimated to be €0-2m (Rijkswaterstaat, 2015). It is assumed that these costs were similar in 2015.

Haringvliet Locks Management Decree on the partial opening of the Haringvliet locks
As from 2018 the Haringvliet locks will be ‘set ajar’ at moments when the water level in the Haringvliet estuary is lower than the seawater level. At these moments, seawater is allowed to flow into the estuary through the locks. Because the Haringvliet Locks Management Decree also stipulates that sufficient fresh water is to remain in the area, compensatory measures are required to facilitate agriculture and the supply of drinking water.

The total budget for this project is €80m and will be funded by the national government (Rijkswaterstaat), the local waterboard (Hollandse Delta) and the drinking water company (Evides). The project will be completed by 2018. Of the total budget, €32m was spent in 2015. After completion, the annual monitoring costs will be around €300,000 (Ministerie van Infrastructuur en Milieu, 2017).

Table 2.1 shows the final cost estimate of approximately €62m in 2015 for measures related to the physical restructuring of rivers, coastline or seabed.

Table 2.1 *Average annual cost related to the physical restructuring of rivers, coastline or seabed*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Assessment of hydrographic interventions and compensation for effects	D7 1A	N.A.
Relocation of dredged material [a]	D8 O	€30m
Zoning and phasing of activities along the coast	D1 1A	€0-2m
Haringvliet Locks Management Decree [b]	D1 1A	€32m
Total		**€62-64m**

Sources: a) Walker et al. (2011); b) Ministerie van Infrastructuur en Milieu (2017).

2.4 Extraction of non-living resources

This theme includes the following activities: extraction of minerals (rock, metal ores, gravel, sand, shell), extraction of oil and gas, salt and water. In the Dutch part of the North Sea, oil and gas extraction and the mining of sand and shells takes place. The cost of measures to reduce the impact of those activities on the Dutch part of the North Sea environment which have been calculated in this study include sand and shell extraction in specified areas, avoiding turbidity, the treatment of produced water, and mitigation measures related to underwater noise during seismic surveys.

Sand and shell extraction in specified areas

Mining of sand and shells are the only two kinds of surface mining occurring in the Dutch area of the North Sea. Of these two, sand extraction is the most important. In 2015, around 8.1m m^3 of sand was extracted from several specified mining locations (ICES, 2016). Due to environmental concerns, the government only issues permits for certain specified locations. Since these are not all located at the economically most optimal locations there is a cost involved.

The sector estimates that it spends approximately 5% more than in an 'ideal' situation where it is allowed to mine sand and shells in every suitable location (Ecorys, 2007). In 2005, the total turnover for the sector was €48.7m (in that year, 26m m^3 was extracted). The turnover in 2015 is unknown, but for this calculation, the turnover of 2005 is divided by 3, as the amount of extracted sand in 2015 was approximately one third of the amount in 2005; this would make a turnover of €16.2m. As such, the additional costs (5%) are estimated to be €811,000.

Avoiding turbidity

Another measure that relates to sand and shell mining relates to avoiding turbidity. Turbidity refers to the suspension of material from the sea bed in the water due to the process of mining. Higher levels of suspended material interfere with aquatic species metabolism and can interfere with spawning. Certain types of dredging equipment reduce the turbidity but may be more costly. Unfortunately, it was not possible to identify those costs.

Reduction of emissions of pollutants from production water discharges by oil and gas installations

As a result of the process of lifting oil and gas from water-bearing formations, water is discharged by oil and gas installations. This water usually contains oil, heavy metals and Polycyclic aromatic hydrocarbons (PAHs). Because of this, this water must be treated and tested prior to being discharged overboard. This measure is mandatory for all platforms within the Dutch EEZ.

To calculate the cost of these measures, the same assumptions are used as in the 2011 study as they are probably still valid. The investment cost of treatment plants for produced water on oil and gas platforms in Dutch waters are therefore estimated to be €6.5m This figure consists of two separate elements. The cost of running the treatment plants are estimated to be €5.8m per year. In addition to the day to day costs of treatment, research is also carried out into the process at a cost of €0.7m per year. These costs are summarised in Table 3.2.

The above mentioned costs apply to all platforms operating in the Dutch EEZ. For this study, non-Dutch companies that are operating in the Dutch part of the North Sea have not been separated (this would require further analysis of the ownership structure). As such, these results should be considered as an overestimate.

Reducing the effects of underwater noise during seismic surveys

In 2015, research into the effects of underwater noise (noise accumulation and seismics) was commissioned by the Ministry of Economic Affairs. The cost of this research was €100,000. Further costs for this measure were not made in 2015 due to this measure having not been implemented in that year (until 2016 no requirements relating to environmental effects had been in place). Permit requirements as of 2016 are as follows: application of soft start and acoustic deterrent devices (ADDs) and production of an EIA. These changes in the permit system were made after the publication of the Harbour Porpoise Conservation Plan and the development of MSFD-related policies on underwater noise. Since 2016, only one EIA has been produced, of which the costs are unknown (René Dekeling, pers. comm. 2017, Ministerie van Economische Zaken, 2015).

Limitation of platform lighting on oil and gas platforms
This measure concerns shielding light sources and automatically disconnecting light sources in places on the platform where no work is being carried out. The assumption is that this measure does not lead to significant additional costs.

Table 2.2 shows the final cost estimate of approximately €7.4m in 2015 for measures related to the extraction of non-living resources.

Table 2.2 *Average annual cost related to the extraction of non-living resources*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Sand extraction in specified areas [a, b]	D1 O	€811,000
Avoiding turbidity	D1 O	N.A.
Reduction of discharges of pollutants from oil and gas installations [c]	D8 1A	€6.5m
Reducing the effects of underwater noise during seismic surveys	D11 O	€100,000
Limitation of platform lighting on oil and gas platforms	D11 1B	0
Total		**€7.4m**

Sources: a) ICES 2016; b) and c): Walker et al. (2011).

2.5 Production of energy

This theme includes the following activities: generation of renewable energy (wind, wave and tidal power), including infrastructure, generation of non-renewable energy, transmission of electricity and communications (cables). The costs of measures to reduce the impact of those activities on the Dutch part of the North Sea environment which have been calculated in this study include licensing procedures for windfarms, assessment of (large-scale) interventions and relevant compensation and positioning wind farms in less than optimal locations.

Licensing procedure for wind farms
In 2015, three offshore wind farms were in operation in the Dutch area of the North Sea: Egmond aan zee (108 megawatt (MW), located near Egmond aan Zee), the Princess Amaliawindpark (120 MW, located near IJmuiden) and Eneco Luchterduinen (129 MW, located near Zandvoort). During 2015, a total of 7 wind farms (Borssele 1, 2, 3, 4, Hollandse Kust 1, 2, 3) were going through the planning process for a total capacity of 3,592 MW (4C Offshore, 2017).

The period when wind farms are constructed (i.e pile-driving) is considered to be the time when the largest effects on the marine environment take place, due to impulsive noise. Studies have shown that underwater noise can adversely affect marine species, especially cetaceans. In Dutch waters, the Harbour Porpoise is the most common cetacean and most affected by underwater noise, showing avoidance behaviour or effects on its hearing capacity. To mitigate for these effects, several measures are implemented or have been proposed. The annual cost of these measures are estimated to be €18-72m (Royal HaskoningDHV, 2015).

During the construction phase of the next wind farm, a new measure will be in effect: a maximum permissible noise level has been prescribed depending on the building season and the number of piles to be driven. This measure had not been implemented in 2015 (René Dekeling, Ministry of Defense, pers. comm. 2017).

Assessment of (large-scale) interventions and relevant compensation
To calculate the cost of producing EIAs, the same assumptions are used as in the 2011 study (Walker et al., 2011), with updated information on planned wind farms in 2015:

1. During 2015, a total of 7 wind farms were going through the planning process for a total capacity of 3,592 MW. The capacity of the planned wind turbines is between 6 and 12 MW (the exact type of turbine for Hollandse Kust 1, 2 and 3 will be decided upon in 2019). In total, between 343 and 439 turbines are planned (4C Offshore, 2017).
2. The process of getting a permission to build a wind farm in the North Sea can take around seven years. Therefore, the costs of EIAs are considered to be evenly spread across this period;
3. In the calculation of the cost of producing EIAs, the same percentages were used as in the 2011 study, which were derived from the Ministry of Infrastructure and the Environment. These referred to the percentage of the development/construction costs attributable to EIAs for land-based wind turbines and range from 0.001% to 1% of the total costs depending on the size of the wind farm. These land-based figures can only be used as a rough estimate. Given that EIAs for activities in the North Sea require substantial efforts to produce and also given the indications of costs of land-based wind farms, 0.5% was used for this study. This percentage fits within the range of land-based percentages.
4. It is assumed that the investment costs of one turbine are between €2,900-€4,320 for every kW (IRENA, 2012). This estimate includes costs such as the grid connection, etc. The actual cost for the turbine itself is estimated to be 30-50% of this amount, which is approximately €870-€2.160 for every KW, or €0.87-2.16m for every MW.
5. As such, the total cost estimate of this measure in 2015 is calculated to be 3,592 MW * (€0.87-2.16m per MW) * 0.5% / 7 = €2.3-5.5m.

The positioning of wind farms in less than optimal locations
Wind farms may be required to be positioned in less than optimal locations for (amongst others) environmental reasons. This could result in higher costs for high voltage power cables (greater distance implies higher costs of expensive cables). The costs related to this measures in 2015 are unknown and require further study.

Table 2.3 shows the final cost estimate of €65.4-176.6m in 2015 for measures related to the production of energy.

Table 2.3 *Costs related to the production of energy*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Licensing procedure for wind farms [a]	D11 1A	€18-72m
Assessment of (large-scale) interventions and relevant compensation [b]	D1 1A	€2.3-5.5m
Positioning wind farms in less than optimal locations	D1 O	N.A.
TOTALS		**€65.4-176.6m**

Sources; a) Royal HaskoningDHV (2015); b) 4C Offshore (2017), IRENA (2012).

2.6 Extraction of living resources

This theme includes the following activities: fish and shellfish harvesting (professional, and recreational), fish and shellfish processing, marine plant harvesting, hunting and collecting for other purposes. The costs of measures to reduce the impact of these activities on the Dutch part of the North Sea environment which have been estimated and calculated in this study (and will be further elaborated below) include certain subsidies from the European Maritime and Fisheries Fund, costs related to marine protected areas, certification of the fisheries, and the Green Deal Fishery for a Clean Sea.

In the overview below, the costs to government in terms of FTE are not mentioned, as these are mentioned in the 'government' section. These excluded costs to government also include costs for administrative staff involved in the policy preparation and coordination (such as CFP related work), preparing and granting subsidies and the cost of projects outsourced to research institutes, permit licensing, coastguard and inspection, etc.

Common Fisheries Policy and the European Maritime and Fisheries Fund
In the current situation, the fisheries sector is both legally restricted and financially supported by the EU and The Netherlands. The main management tools are the CFP (Common Fisheries Policy) and the EMFF (European Maritime and Fisheries Fund). A main objective is to manage fish stocks at the same level as a maximum sustainable yield (MSY) with the corresponding maximum fish mortality rate (Fmsy). (ICES) advises (bi)annually on total allowable catches

The exact costs related to the CFP are unknown and require further study. These costs include costs for administrative staff involved in the policy preparation and coordination, projects outsourced to research institutes, permit licensing, coastguard and inspection, etc. Costs for the sector include measures that are required under the technical measures policy. These costs are unknown and require further study.

Most of the financial support granted through the EMFF can be assumed to be spent to prevent degradation of the marine environment. Some of the support provided by the EMFF requires co-finance by the private sector. Table 2.4 shows the relevant subsidies and the amount of co-financing by the sector. The period of this subsidy is referred to as being 2014-2020, but in reality the costs are spent during a 6 (instead of a 7) year period:

Table 2.4 *Average annual EMFF subsidy and related private sector costs for fisheries in the Dutch part of the North Sea, 2014-2020, €m*

Measure	Cost to the government	Cost to the private sector (co-financing 50%)	Total cost (6 year period)	Annual cost estimate government	Annual cost estimate private sector
Management measures	2.8		2.8	0.5	-
Investments in the discard ban	8.6	4.3	12.9	1.4	0.7
Innovation for ecological sustainability	20	10	30	3.3	1.7
Use of unwanted catches	2.8	1.4	4.2	0.5	0.2
Partnerships	5.8		5.8	1.0	-
Innovations in the aquaculture	6.6	3.3	9.9	1.1	0.6
Data collection fish stocks	33.3		33.3	5.6	-
Enforcement and control	25.3	12.7	38	4.2	2.1
Facilitating the discard ban	2.8	1.4	4.2	0.5	0.2
Promotion to protect the North Sea	2.2		2.2	0.7	-
Expertise about the sea	2.2		2.2	0.4	-
Total	**112.4**	**33.1**	**145.5**	**18.7**	**5.5**

Source: Ministerie van Economische Zaken (2015).

The contribution of the government to EMFF-related measures which can be attributed to having a positive effect on the North Sea Environment amounts to €112.4m for the period 2014-2020 (€18.7m per year), but some co-financing by the sector is required. On average a co-financing contribution by the sector of 50% is required; which means €33.1m in total, or €5.5m on an annual basis. The total costs for 2015 are therefore estimated to be €24.2m. The final step is to adjust for the fact that the benefits of subsidies will not just be felt in the Dutch part of the North Sea but also in any area where Dutch fishing vessels operate. The percentage of sea days that Dutch fishing vessels fished in the Dutch part of the North Sea is estimated to be between 60 and 70% (Wageningen Economic Research, internal information, 2017). As such, the final value of EMFF related costs in 2015 are estimated to be between €14.5m (60% of €24.2m) and €16.9m (70% of €24.2m).

In some cases the costs of all EMFF-related measures can be counted as real costs to society. In some cases they cannot. This is because the costs can be considered as an investment which the private sector makes in order to increase its revenues. The private sector will only make this investment if the revenues are higher than the costs. In this way, not all costs are 'real costs' (Walker et al., 2011). Therefore, the figures mentioned above are considered to be an upper bound.

Restriction on fishing in the coastal zone
This measure refers to restrictions to prevent and mitigate significant impact on habitats and species under the Birds and Habitats Directive of seabed-disturbing fishing techniques in the Natura 2000 areas of Voordelta, the Raan Flats and the North Sea coastal zone are subject to restrictions.

The VIBEG ('Visserij in Beschermde Gebieden') Agreement stipulates that a maximum of 5 fisheries vessels using towed gear are allowed to enter the Natura 2000 areas of Voordelta, the Raan Flats and the North Sea coastal zone. The additional costs for the fisheries are the costs to avoid these areas and to fish in other areas. These additional costs can consist of extra fuel, less time to fish (it takes longer to reach the fishing grounds) and possibly less earnings (due to being forced to fish in less favorable fishing areas). The annual costs of these measures are estimated to be less than €11.5m (Veeren, van der and Keijser, 2012).

Expansion of scope of Nature Conservation Act and Flora and Fauna Act
The scope of the Nature Conservancy Act 1998 and the Flora and Fauna Act has been expanded to include the Exclusive Economic Zone (EEZ) for which the central government remains the competent authority. In this way, the Natura 2000 areas outside the territorial waters that have already been put forward can actually be designated and management plans can be created. This ensures that the assessment framework for granting a permit for activities at sea, the Birds and Habitats Directive and the protection of species all have a greater impact. The costs of this measure in 2015 are government related, are unknown and require further study.

Restrictions on fishing that disturbs the seabed at cleaver Bank, Dogger Bank, Oyster Grounds and the Frisian Front
In Natura 2000 areas Cleaver Bank and Dogger Bank (Habitat Directive areas in the EEZ) restrictions are proposed for seabed-disturbing fishing techniques. In the Frisian Front area seasonal closures are being implemented for fixed net and drift net fishing because of foraging guillemots (Bird Directive area in the EEZ). These FIMPAS (Fisheries Measures in Protected Areas) and Dogger Bank Agreements will be implemented in combination with research and monitoring for further knowledge acquisition.

A management plan for the Doggerbank has been proposed and will enter the decision-making procedure in 2017. A final decision on the management plan is expected to be made in 2018. Decisions on the Frisian Front, Central Oyster Grounds and Cleaverbank are expected to be made at a later stage. In 2015, fishing restrictions were not in place (and therefore there were no additional costs). Costs that have been incurred in 2015 include FTE and research and stakeholder participation costs to the government, the fisheries sector and NGOs. The exact amount of these costs are unknown (Oostenbrugge, 2017, pers. comm.).

In addition to existing[2] and planned policies, the following policy task has been formulated regarding additional seabed protection as announced in Marine Strategy Part 1: In addition to the implementation of the Birds and Habitats Directive and to generic commitment to make fishing more sustainable, protection will be offered to the seabed ecosystem in the areas of the Frisian Front and Central Oyster Grounds. These are considered search areas for spatial protection measures. Costs that have been incurred in 2015 include FTE and research costs to the government, the fisheries sector and NGOs. The exact amount of these costs are unknown (Oostenbrugge, 2017, pers. comm.).

Sustainable Seafood Certification
The costs for certification relate to the costs for assessments, setting up and running a monitoring system, and annual audits. One of the largest certification bodies is the Marine Stewardship Council

[2] This measure is related to the (government) measure 'Expansion of scope of Nature Conservation Act and Flora and Fauna Act'.

(MSC). The costs related to MSC certification differ for each type of fisheries and type of fish. On average, these costs can be around 0.25 eurocents per kg of certified fish. In 2015, the annual costs for the Dutch fisheries were estimated to be €350,000 for plaice and €350,000 for grey shrimp (Hans Nieuwenhuis, MSC, pers. comm. 2017). In total this is €700,000.

Standards for contaminants in fish and fish products
Levels of contaminants in fish and fish products must meet the norms set by national and international legislation. High levels of contaminants do not occur in the Netherlands, therefore, no costs are attributed to this measure.

Green Deal: Fishery for a Clean Sea
The Green Deal Fishery for a Clean Sea was signed in 2014. It is a collaborative strategy with measures, signed and agreed upon by all signatories. Signatory for the fisheries sector is VisNed. In addition, it was signed by seven fishing ports, the cities of Urk and The Hague, two waste collectors, the North Sea Foundation and the ProSea Marine Education Foundation. By signing the Fishery for a Clean Sea Green Deal, the signatories commit themselves to tackle the waste issue by taking measures such as Fishing for Litter, more effective waste management, and developing alternatives for dollyrope. The estimated annual cost of these measures are shared between the government, private sector and NGOs and are estimated to be between €360,000 and €465,000. This amount may increase as more parties become signatories (Ecorys, 2014).

Minimising and phasing out of discards (landing obligation)
The discard band has not yet been fully implemented and the way in which this will be done is currently being discussed (exceptions, etc.). A full implementation would cost the fisheries sector anywhere between €6-14m (Buisman & van Oostenbrugge, 2013). The implementation process is gradual, the EMFF sourced costs in 2015 are estimated to have been around €1.4m for the government and €0.7m for the Dutch fisheries sector; €2.1m in total (Ministerie van Economische Zaken, 2015). These numbers have to be adjusted for the fact that the benefits of subsidies will not just be felt in the Dutch part of the North Sea but also in any area of the where Dutch fishing vessels operate. The percentage of sea days that Dutch fishing vessels fished in the Dutch part of the North Sea is estimated to be between 60 and 70% (Wageningen Economic Research, internal information, 2017). As such the final value of the costs in 2015 are estimated to be between €0.4 and 0.5m for the fisheries sector and between €0.8 and 1.0m for the government.

Note: the costs of this measure are already included in the measure ‘Common Fisheries Policy and the European Maritime and Fisheries Fund’ mentioned above and will not be mentioned separately in the table below.

Encouraging alternative fishing gear
This measure relates to the development of alternative and innovative methods enabling more selective fishing and causing less damage. If possible, these methods will be put into practice.

The EMFF sourced costs for this measure in 2015 are estimated to have been around €3.3m for the government and €1.7m for the fisheries sector; €5m in total (Ministerie van Economische Zaken, 2015). These costs are adjusted to the fact that the benefits of subsidies will not just be felt in the Dutch part of the North Sea but also in any area of the where Dutch fishing vessels operate. The percentage of sea days that Dutch fishing vessels fished in the Dutch part of the North Sea is estimated to be between 60 and 70% (Wageningen Economic Research, internal information, 2017). As such the final value of the costs in 2015 are estimated to be between €1.0 and 1.2m for the fisheries sector and between €2.0 and 2.3m for the government.

Note: the costs of this measure are already included in the measure ‘Common Fisheries Policy and the European Maritime and Fisheries Fund’ mentioned above and will not be mentioned separately in the table below.

Standards for contaminants in fish and fish products.
Levels of contaminants in fish and fish products must meet the norms set by national and international legislation. High levels of contaminants do not occur in the Netherlands (OSPAR has shown that the doses in fish products are far below the international norms for human exposure to contamination), therefore, no costs are attributed to this measure.

Marine environmental awareness course
The marine environmental awareness course is aimed at gaining knowledge and awareness of the prevention of pollution to the marine environment. Those who have successfully completed the course will be able to demonstrate knowledge and understanding of the importance of preventing pollution to the (marine) environment. The cost of this course in 2015 was €40,000 and was paid for by the government (Tim Haasnoot, ProSea, pers. comm. 2017).

Table 2.5 shows the final cost estimate of €37.4-37.9m in 2015 for measures related to the extraction of living resources.

Table 2.5 *Estimated costs related to the extraction of living resources in 2015, €m*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Common Fisheries Policy and the European Maritime and Fisheries Fund [a]	D3 1B	14.5-16.9
Restriction on fishing in the coastal zone [g]	D1 1A	>11.5
Expansion of scope of Nature Conservation Act and Flora and Fauna Act [b]		N.A.
Restriction on fishing that disturbs the seabed at cleaver Bank, Dogger Bank, Oyster Grounds and the Frisian Front [b]		N.A.
Sustainable Seafood Certification [c]	D3 1B	0.7
Standards for contaminants in fish and fish products	D9 1A	--
Green Deal: Fishery for a Clean Sea [d]		0.4-0.5
Minimising and phasing out of discards (landing obligation) [a,e]	D3 1B	--
Encouraging alternative fishing gear [a]		
Standards for contaminants in fish and fish products	D9 1A	N.A.
Marine Environmental Awareness Course [f]	D10 1A	0.0
Total		**>29.1-32**

Source: a) Ministerie van Economische Zaken (2015); b) Oostenbrugge (2017), c) Nieuwenhuis (2017); d) Ecorys (2104); e) Buisman & van Oostenbrugge (2013); f) Tim Haasnoot (2017); g) Veeren, van der and Keijser (2012).

2.7 Cultivation of living resources

This category includes the following activities: aquaculture – marine, including infrastructure, aquaculture – freshwater, agriculture and forestry. These are not all applicable to the situation in The Netherlands. For this study, the following measures are considered to be related to this category: the prevention of the introduction of non-indigenous species in North Sea waters, Manure Policy (Nitrates directive) and the Admission Policy for Plant Protection.

Conditions attached to permits to prevent the spread of non-indigenous species
To prevent the introduction of non-indigenous species in the North Sea waters, the aquaculture sector is obliged to take measures when importing shellfish from abroad. Originally, these shells were imported, cleaned of marine debris and sold. The marine debris was then dumped into the Oosterschelde, along with the debris from the Dutch shells. Since some of the debris from imported shellfish include non-indigenous species which pose a hazard to the marine environment, it was decided by (Natura 2000) law to forbid the dumping of non-indigenous species. The total costs related to measures to prevent the introduction of non-indigenous marine plants and animals from entering the Oosterschelde and North Sea are estimated to be around €260,000 a year. These costs include monitoring, legal advice, permit application and quarantine measures (Walker et al., 2011).

Management of Natura 2000 areas (non- indigenous species)
The management programmes for the Natura 2000 areas include measures geared towards preventing the import of non-indigenous species and combating the presence of invasive non indigenous species. The type of measures differs for each Natura 2000 area and depends on the nature objectives. The above-mentioned mussel transition policy, which aims to prevent the introduction of invasive non indigenous species that are harmful to the Wadden Sea, serves an example of this. Regular checks are carried out to enforce this measure. The administrator can intervene if invasive non-indigenous species are seen to be introduced. These costs are unknown and require further study.

Regulation on the prevention and management of invasive species
EU issued a requirement in 2016 to take preventative measures, to rapidly eradicate invasive species at an early stage of establishment, and to take measures to control widespread, established non-indigenous species, the EU issued a requirement in 2016 to take preventative measures, to rapidly eradicate invasive species at an early stage of establishment, and to take measures to control widespread, established non-indigenous species. This regulation came into force on 1 January 2015. This measure will take effect in 2016. This measure relates to the development of an action plan that includes monitoring and taking (preventive) measures. The costs of this measure are unknown and require further study.

Manure Processing (European Nitrates directive)
Farmers are limited in the number of head of cattle and are required to sell and treat the surplus amount of manure (nitrates may eventually end up in the North Sea) may. The Cabinet has introduced mandatory manure processing so as to achieve a balanced fertiliser market. This measure requires farmers to have a percentage of their surplus manure treated for sale outside the Dutch fertiliser market. This percentage is determined by the government. The amendment to the Manure Act, which regulates the mandatory treatment of manure, came into effect on 1 January 2014.

The total cost of this policy for the agricultural sector is estimated to be 159m, including savings on fertiliser. These costs relate to the prevention of nitrate emissions to groundwater and surface water (De Koeijer et al., 2015). Due to insufficient information, it is not exactly clear which part of these costs can be attributed to protection of the Dutch part of the North Sea Environment. Based on expert opinion (Rijkswaterstaat, internal information), it is assumed that 5-30% of these costs can be attributed to the North Sea environment. The total costs that will be attributed to this measure are therefore estimated to be in the range of €7.1-47.7m.

Deltaplan Agricultural Watermanagement
The Deltaplan Agricultural Watermanagement refers to a collaboration project between LTO (the Dutch Federation of Agriculture and Horticulture) and the waterboards on water quality related measures (Deltaplan Agrarisch Waterbeheer, 2017). The specific measures and cost of these measures in 2015 are unknown and require further study.

Admission Policy for Plant Protection
This measure refers to soil decontamination and the reduction of pesticides (Action Plan for Sustainable Plant Protection). The annual total cost related to this measure is estimated to be €18m for agriculture and €18m for greenhouse horticulture (De Koeijer et al., 2015). Of this measure, 5-30% will again be attributed to the Dutch part of the North Sea environment. The total costs that will be attributed to this measure are therefore estimated to be in the range of €1.8-10.8m

Table 2.6 shows the final estimate of €9.1-58.8m in 2015 for measures related to the cultivation of living resources.

Table 2.6 *Average annual cost related to the cultivation of living resources*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Conditions attached to permits to prevent the spread of non-indigenous species [a]	D2 1A	€260,000
Management of Natura 2000 areas (non-indigenous species)	D2 1A	N.A.
Regulation on the prevention and management of invasive species	D2 1A	N.A.
Manure Processing (Nitrates directive) [b]	D5 1A	€7.1-47.7m
Deltaplan Agricultural Watermanagement	D5 1B	N.A.
Action Plan for Sustainable Plant Protection [c]	D8 1A	€1.8-10.8m
TOTALS		**€9.1-58.8m**

Sources; a) Walker et al. (2011); b) De Koeijer et al. (2015); c) De Koeijer et al. (2015).

2.8 Transport

This theme includes the following activities: transport infrastructure, shipping, air transport and land transport. The cost of measures to reduce the impact of these activities on the Dutch part of the North Sea environment which have been calculated in this study include the rerouting of shipping lanes, insurance, anti-fouling, emissions to air, ballast water treatment, waste management, and the Green Deal Ship Generated Waste. In 2015, approximately 840 of ships were under Dutch ownership (KVNR, 2017). This section uses the Ecorys (2007) assumption that approximately 10% of Dutch shipping occurs in the North Sea.

Rerouting of shipping lanes

The structure of shipping lanes in the Dutch part of the North Sea was changed as per 1 August 2013. One of the reasons for these reroutings has been to reduce the chances of pollution by reducing the chance of shipping incidents. Other reasons are for example new zoning measures due to the construction of wind farms at sea. These measures have resulted in additional distances for commercial traffic and associated costs. Additional distances incurred by commercial traffic are small when considered individually in the context of foreign going vessels that transit the routes infrequently. Even so, this figure escalates to a large amount when considering all vessels that enter the ports of Rotterdam and IJmuiden on an annual basis. The additional mileage, and therefore costs, is more readily felt by those individual vessels which frequent the ports on a daily basis and classed as regular runners, that is, ferries, feeder vessels and similar.

The total annual cost of these measures to all (Dutch and non-Dutch owned vessels) has been calculated to be €19.3m per year; a distinction between the costs for these two types of vessels has not been made (IMO sub-committee on safety of navigation, 2012). It is not known which percentage of these costs can be attributed to reducing the chances of pollution. Therefore, the annual €19.3m should be considered an upper bound.

Insurance to cover the impact of disasters at sea

This measure refers to both the insurance costs to cover the impact of disasters at sea (i.e. cleaning up oil spills due to collisions) and the costs of contributing to the International Oil Pollution Compensation Funds (IOPC Funds). The insurance costs for an average Dutch ship are between €125,000 and €150,000 for a 10,000 GT (gross tonnage) ship (Ecorys, 2007). This figure is used because approximately 10,000 GT is the average size of a ship under a Dutch ownership (Ecorys, 2007). It is important to note that only a proportion of the total insurance amount can be attributed to avoiding degradation of the marine environment. It is assumed, based on expert opinion, that this proportion is 25% (Ecorys, 2007). For this report, it is also assumed that this proportion is the same for 2015. Based on the number of ships in 2015, the figure is estimated to be €25-30m This figure must then be adjusted to account for the fact that the fund covers all oceans not just the North Sea. In order to do this, the 10% assumption is used. As such the final annual average is between €2.5-3m

In addition to the costs related to insurance, the Dutch oil industry contributes to the International Oil Pollution Compensation Funds (IOPC Funds). These funds are part of an international regime for liability and compensation for oil pollution damage caused by oil spills from tankers. Under the regime, the owner of a tanker is liable to pay compensation up to a certain limit for oil pollution damage following a leak. If that amount does not cover all the admissible claims, further compensation is available from the 1992 Fund if the damage occurs in a state which is a member of that fund. Additional compensation may also be available from the Supplementary Fund if the state is a member of that fund as well. The IOPC Funds are financed by levies on certain types of oil carried by sea. The annual contributions of the IOPC members varies depending on the amount which the fund needs to pay out.

In 2015, the Netherlands (including Bonaire, Sint Eustatius and Saba) contributed €485,340 to the '1992 Fund' (calculating with an annual average conversion rate in 2015 of 1.3 euro/pound), which is 8.7% of the total contributions. In 2015, no levies were made in respect of contributions to the 'Supplementary Fund' (IOPC, 2016) Again, the 10% assumption is used as cost related to the North Sea. As such, the cost in 2015 is estimated to be €48,534.

Preparation, coordination and international cooperation of oil disaster and incident control at sea
This measure concerns the coordination of disaster and incident control (i.e. preparedness, cleanup, exercises, international cooperation) in the North Sea by the Dutch government (Rijkswaterstaat). The costs of this measure are estimated to be €950,000-€1,000,000 on an annual basis (Arno Nieuwenhuize, Rijkswaterstaat Zee en Delta, pers. comm. 2017).

Water quality related measures
Statistics Netherlands (CBS) collects data on the cost of measures in the shipping sector related to water quality. The measures included in their calculation include measures relating to ship's waste and litter, chemical substances and oil (all MARPOL related). The cost of these measures are not provided separately but collectively. For 2015, data are not available, but for the latest year in which data are available, 2013, the total cost of these measures are calculated to be €33m (CBS, 2017). Of these total costs, 10% can be attributed as to having an effect on the North Sea, which would be €3.3m.

Implementation of Hull Fouling Guidelines against growth of non-indigenous species on ships' hulls
In order to minimise the impact of marine species attaching themselves to ships, many ships are protected by antifouling coatings. Many types of coatings, however, have been found to be toxic to marine organisms. For example, extremely low concentrations of tributyltin moiety (TBT), which was the most commonly used anti-fouling agent, caused defective shell growth and development of male characteristics in female dog whelks.

Concerns about the environmental and health effects of these paints have led to the ban of these compounds in marine coatings by the International Maritime Organization (IMO). The International Convention on the Control of Harmful Anti-fouling Systems on Ships was adopted in 2001 and came into force in 2008 (IMO, 2010). The additional annual cost of TBT free anti-fouling material taken by the Dutch shipping industry are unknown and require further study. These costs may also be already included in the measure '*Water quality related measures*'.

Ban on the discharge of garbage by ships (MARPOL Annex V)
In 2013, the revised MARPOL Annex V regulations came into force. According to the revised Annex V it is no longer allowed to discharge any garbage into the sea with the exception of some categories like food waste. All Dutch ports have reception facilities where ships can dispose of their ship generated waste and cargo residues. The total costs to shipping (all ships visiting Dutch ports) excluding fisheries for ship generated waste and cargo residues in 2015 are €24.4m (Coen Peelen, Ministry of Infrastructure and the Environment, pers. comm. 2017).

Ban on discharging ships' waste from inland shipping vessels
Under the Ships' Waste (Rhine and Inland Waterways) Decree and the Ships' Waste (Rhine and Inland Waterways) Regulation, all passenger and hotel ships with a capacity of more than 50 people are prohibited from discharging domestic waste water into surface water effective 1 January 2012. The

Ships' Waste Decree is the implementation of the 2009 Convention on the collection, deposit and reception of waste produced during navigation on the Rhine and inland waterways. The costs related to this measure are unknown and requires further study.

Green Deal Ship Generated Waste
The Green Deal Ship Generated Waste was signed in 2014 by 15 parties and is a voluntary agreement between private/societal parties and central government with the purpose to work together on green growth. The signatories include port authorities, ship owners, ship suppliers, port reception facilities, enforcement authority and NGOs. The Green Deal Ship Generated Waste is a collaborative strategy with measures, signed and agreed upon by all signatories and focuses on waste prevention in the provisioning of ships, waste inspections, separate disposal and the alignment of procedures in the ports, among other things. The goal is to optimise delivery of ship-generated waste and promote separated delivery of plastic ship-generated waste a substantial reduction. As part of this Green Deal, several measures were taken by the signatories in 2015. The specific costs of these measures are unknown and require further study.

Countering the spread of species via ballast water/ Implementation of protocols for exemptions after Ballast Water Convention comes into force
On the 8th of September 2017 the International Ballast Water Management Convention will enter into force after which, within a timeframe of five years, all ships undertaking international voyages are obliged to meet a certain discharge standard when discharging ballast water. The exact date on which a ship needs to comply varies and depends on the expiry date of the ship specific IOPP certificate.

In order to meet this requirement it is expected that most ships will be equipped with a ballast water treatment system. The costs of these treatment systems for each single ship are estimated to be around €0.3 to €1.5m, depending on the total ballast water capacity and the ballast water flow rate of the ship. Most of these systems will be installed after 2017 (when the International Ballast Water Management Convention will enter into force). It is not known how many of Dutch ships were already equipped with a treatment system in 2015 (KVNR, 2017). As such, the costs related to this measure in 2015 are unknown and will not be included in the calculation.

The reduction of SOx and NOx emissions
A further measure relates to on SOx and NOx emissions from ship exhausts. Some of the potential environmental impacts associated with a reduction in shipping emissions include reductions in sulphur and nitrogen deposition and reductions in acidification and eutrophication. New MARPOL standards for the emissions of sulphur have entered into force on 1 January 2015. A maximum emission of 0.1% is allowed in Sulphur Emissions Control Areas (SECAs), which are located in the North Sea, Baltic, the Channel and along the North American coastline.

These regulations require a reduction in emissions through changing fuel use or installation of scrubbers or any other technical measure such as the use of low sulphur fuel oil (KVNR, 2017, pers. comm.):

1. Installation and use of exhaust gas cleaning systems, such as scrubbers. Initial costs for such installations for an average ship (10,000 GT) average between €1.5-3m. The estimate is that approximately 5-10% of all ships under Dutch ownership use such installations (40-80 ships). These have mainly been installed during two consecutive years: 2014 and 2015, during which costs have been made. The assumption is that the number of installations is distributed equally over 2014 and 2015. As such, in 2015, the costs are estimated to have been €60-120m; if again 10% of these costs are attributed to the North Sea, the estimated costs would be €6-12m In this figure, annual operational costs have been omitted due to those being of a wide ranging variety and dependent on the type of ship and the area where a ship is sailing (i.e. inside or outside SECAs).
2. The use of low sulphur fuel oil (also called Marine Gasoil or MGO), or LNG (only applied in 2% of the vessels). The cost of MGO in comparison to regular fuel is about twice as much. The total additional cost of this type of fuel is unknown and not included in this calculation.

Stricter NOx standards (NOx Tier III) for newly built ships will enter into force on 1 January 2021 in the following NECA (NOx Emission Control Area) areas: North Sea and the Baltic. These new measures are already in place since 1 January 2016 along the North American coastline and apply to ships that have been newly built since. The cost of this measure is unknown and would require further study study.

The reduction of discharges of paraffin-like substances and other high-viscous substances
Like SO2 and NOX, paraffin like substances are included in MARPOL Annex II. Some discharges are currently still allowed, some not. The cost related to this measure is unknown and requires further study.

Implementation of IMO guidelines on the reduction of underwater noise from commercial shipping
This is a voluntary guideline, not a national (Dutch EEZ) restriction or mandatory measure. Based on recommendation at IMO, international guidelines might be developed in the future. The cost for this voluntary guideline are unknown and as such are not included in this analysis.

Marine environmental awareness course
The marine environmental awareness course is aimed at gaining knowledge and awareness of the prevention of pollution to the marine environment. Those who have successfully completed the course will be able to demonstrate knowledge and understanding of the importance of preventing pollution to the (marine) environment. The cost of this course in 2015 was €70,000 and was paid for by the private sector (Tim Haasnoot, ProSea, pers. comm. 2017).

Table 2.7 shows the final estimate of €56.2-63m in 2015 for measures related to transport.

Table 2.7 *Average annual costs for transport*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Insurance to cover the impact of disasters at sea [a]	D8 O	€2.5-3m
IOPC fund [b]	D8 O	€48,534
Reduction of pollution by reducing shipping incidents (rerouting shipping lanes) [c]	D8 1A	<€19.3m
Preparation, coordination and international cooperation of oil disaster and incident control at sea	D8 1A	€0.95-1m
Water quality measures [d]		€3.3m
Implementation of Hull Fouling Guidelines against growth of non-indigenous species on ships' hulls [e]	D2 1B	N.A.
Ban on the discharge of garbage by ships (MARPOL Annex V) [f]	D10 1A	€24.4m
Ban on discharging ships' waste from inland shipping vessels	D10 1A	N.A.
Green Deal Ship Generated Waste	D10 1A	N.A.
Countering the spread of species via ballast water	D2 1B	N.A.
The reduction of SOx and NOx emissions (MARPOL Annex II) [h]	D8 1A	€6-12m
The reduction of discharges of paraffin-like substances (MARPOL Annex II)	D8 1A	N.A.
Implementation of IMO guidelines on the reduction of underwater noise from commercial shipping	D11 1B	N.A.
Marine Environmental Awareness Course [i]	D10 1A	€0.0m
TOTALS		**€56.2-63m**

Sources; a) Ecorys (2007); b) IOPC (2016); c) IMO sub-committee on safety of navigation (2012); d) CBS (2017); e) CBS (2017);
f) Coen Peelen, Ministerie van Infrastructuur en Milieu, pers. comm. 2017; g) KVNR (2017); h) Tim Haasnoot (2017).

2.9 Urban and industrial uses

This theme includes the following activities: urban uses, industrial uses, waste treatment and disposal. Although these activities are land-based, they can have significant effects on the North Sea environment: as water drains into the sea it directly affects pollution and eutrophication levels in the North Sea, the same goes for air related pollution. The cost of measures to reduce the impact of these activities on the Dutch part of the North Sea environment which have been calculated in this study include urban and private waste water treatment, the prevention and limitation of industrial emissions and Water Framework Directive related measures.

It is important to note that expenditure related to inland water quality measures is or might not be totally aimed at improving the marine environment. Some expenditures can be considered to be irrelevant for the marine environment. For others only a percentage of the costs are spent to avoid degradation of the marine environment. In this section, costs are estimated based on the assumption that a certain percentage of the relevant costs can be attributed to the marine environment. These assumptions will be further explained.

Urban and private waste water collection, transport and treatment
The EU Urban Waste Water Treatment Directive protects the environment against the adverse effects of discharging urban waste water. This directive is particularly important for the Netherlands for the removal of nutrients. The total annual cost related to the collection and transport of waste water in The Netherlands was €1.672m in 2013, the cost related to the treatment of this water €1.354m. In total, the annual cost of collection, transport and treatment of waste water amounts to €3.026m (Twijnstra Gudde – Tauw, 2015). For emissions to surface water the assumption is that 5-30% of these costs can be attributed to the North Sea environment (Rijkswaterstaat, internal information). Of this water, 5-30% will finally end up in the North Sea. Therefore, it is assumed that 5-30% of this measure can be attributed to having a potential effect on the North Sea environment. The cost of urban waste water is estimated to be €151-908m.

The total costs of private sewer treatment installations are estimated to be €138m in 2014 (CBS, 2017). This relates to measures to prevent emissions of waste water to surface water. For emissions to surface water the assumption is used that 5-30% would finds its way to the North Sea. Therefore, it is assumed that 5-30% of this measure can be attributed to having a potential effect on the North Sea environment, the cost of which would be €6.9-41.4m.

As such, the total costs of urban and private waste water treatment that can be attributed to the North Sea is estimated to be €158-949m.

Improvement of purification efficiency of sewage treatment plants
District water boards have the intention or are already working to further improve the purification efficiency of a substantial number of the relevant STPs before 2021. The additional costs of this measure in relation to the measure 'urban waste water treatment' are unknown and would require further study.

European Water Framework Directive (WFD)
The European Water Framework Directive (WFD) sets standards for the quality of the surface water (coastal water, rivers and lakes, drainage ditches) and the ground water. The Netherlands has set up a large package of measures to meet these standards by improving and protecting the water quality of rivers, lakes, the sea and ground water (these measures are not related to waste water treatment). The total annual cost related to these measures in The Netherlands was €333m in 2013 (Twijnstra Gudde – Tauw, 2015). For emissions to surface water the assumption is used that 5-30% of this water will finally end up in the North Sea. Therefore, it is assumed that 5-30% of this measure can be attributed to having a potential effect on the North Sea environment. As such, the cost of this measure is estimated to be €17-182m.

Preventing and limiting industrial emissions
These measures include: permit regulations, use of state-of-the-art technology, the application of regulations as contained in the European reference documents (BREFs), and use of the emission-immission test when assessing emissions into *surface* water. These costs are unknown and require further study (source: Adam Walker, CBS, pers. comm. 2017).

Implementation of the Bathing Water Directive
The quality of the bathing water, which means also of the swimming locations that the provinces have designated in the coastal waters, must meet. The main risks for exceeding the swimming water quality norms are pollutants from the land, such as sewage overflows and the presence of dogs and horses on the beach. In some instances, however, commercial vessels and pleasure craft also pose a risk. The costs are related to the following two sub-measures: 1) monitoring of bathing water quality: €60,000 (Rijkswaterstaat, 2015). 2) Measures to prevent sewage spilling into the sea. These costs are unknown and would require further study.

Reduction of environmental risks ensuing from major accidents
Companies must at least have a safety policy and a safety management system. Companies and plants that operate with large quantities of hazardous substances must also draw up a Safety report. The EU 'Seveso Directive' relating to this measure applies to more than 10 000 industrial establishments in the European Union where dangerous substances are used or stored in large quantities, mainly in the chemical, petrochemical, logistics and metal refining sectors (European Commission, 2017).

The final total cost estimate for land-based sources in 2015 is approximately €175-1,131m. The derivation of this is shown in Table 2.8 for measures related to urban and industrial uses.

Table 2.8 *Average annual cost related to urban and industrial uses*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Urban and private waste water collection, transport and treatment [a]	D5 1A	€158-949m
Improvement of purification efficiency of sewage treatment plants [a]	D5 1A	N.A.
European Water Framework Directive (WFD) [a]	D5 O	€17-182m
Preventing and limiting industrial emissions [b]	D8 1A	N.A.
Implementation of the Bathing Water Directive [c]	D8 1A	>€60,000
Reduction of environmental risks ensuing from major accidents [d]	D8 1A	N.A.
Total		**€175-1,131m**

Source: a) Twijnstra Gudde – Tauw, 2015; b) CBS (2017); d) Rijkswaterstaat (2015); e) N. A.

2.10 Tourism and leisure

This theme includes the following activities: tourism and leisure infrastructure and tourism and leisure activities. Although these activities are (mostly) land-based, they can have significant impacts on the North Sea environment: as water drains tourism and leisure related waste into the sea, it directly affects the North Sea environment. The cost of measures to reduce the impact of these activities on the Dutch part of the North Sea environment include the costs related to the removal of beach litter, the Green Deal Clean Beaches and the Clean Meuse/Clean Rivers initiative.

Cleaning campaigns: removal of beach litter
Beach litter comes from many sources, including fisheries, shipping and inland sources. Municipalities along the coast have measures in place associated with the removal of beach litter. For most municipalities, the potential economic impact of marine litter on tourism provides the principal motivation for removing beach litter. The city of The Hague, for example, spends around €1,266,000 annually on its beach cleansing programme (Mouat et al., 2010). The total cost that municipalities in the Netherlands spend on the removal of beach litter is estimated to be between €3.7m and €5.3m, 70% of which is spent on beach cleaning and 20% and 10% respectively on the management of waste facilities and waste disposal (Ecorys, 2012).

Volunteer organisations also remove a significant amount of litter from (mostly non-bathing) beaches, which suggests that the total cost of voluntary actions to remove marine litter could add a considerable number to the cost of beach cleaning.

Green Deal Clean Beaches
The Green Deal Clean Beaches was signed in 2014 by 33 parties. The Green Deal Clean Beaches is a collaborative strategy with measures, signed and agreed upon by the signatories who all assist intensively with cleaning up the Dutch part of the North Sea beaches and keeping them clean. Next to 19 coastal municipalities, the signatories included a range of companies, volunteers, interest groups and civil society organisations. The goal is a substantial reduction, by 2020, in the amount of waste – ranging from empty chips containers (disposables) to cigarette butts – left on the beach by visitors.

The Green Deal is aimed at improving coordination and collaboration between these actors, preventing duplication of work, and enabling the Green Deal partners to learn from each other's experiences. In addition, new specific actions are documented, in which these partners make an additional contribution to clean beaches (Ministerie van Infrastructuur en Milieu, 2014). Measures agreed upon by the actors who signed the Green Deal Clean Beaches include: behavioral influence of beach visitors, Green Key certification, cigarette butts measures, the distribution of ash trays, and monitoring. The annual cost of these measures are calculated to be €650,000 (Ecorys, 2014).

Table 2.9 shows the final cost estimate of €4.4-6m in 2015 for measures related to tourism.

Table 2.9 *Average annual costs related to recreation, €*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
(Cleaning) campaigns: removal of beach litter [a]	D10 1A	3.7-5.3m
Green Deal Clean Beaches [b]	D10 1B	650,000
TOTALS		**4.4-6m**

Sources; a) Ecorys (2012); b) Ecorys (2014).

2.11 Security and defence

This theme includes military operations. The costs of measures to reduce the impact of this activity on the Dutch part of the North Sea environment include costs related to research into, and the mitigation of, underwater noise.

Reducing impulse noise by means of the Code of Conduct for explosive ordnance disposal
Based on recent research the Ministry will develop a new regulation in 2016 to restrict possible harmful effects of explosives clearance and to introduce feasible alternative techniques or mitigating measures. This regulation will enter into force in 2018; no cost were made in 2015. In 2017, the government spent €100,000 on the purchase of pingers and a research study into this topic. When this regulation comes into force, the cost are as of yet unknown but will likely relate to the following measures: changes in the management of explosives clearances (i.e. different methods for explosions, pingers to scare away porpoises, changes in the location of controlled explosions, other techniques to dismantle explosives underwater, bubble curtains, etc). (René Dekeling, pers. comm. 2017).

Regulations on sonar use
To prevent or minimise the harmful effects of anti-submarine sonar signals on marine mammals.
The Ministry of Defence commissioned research into the effects of sonar use and regulations on sonar use. Since 2004, approximately €1.6m was spent on this, which is around €200,000 annually (René Dekeling, pers. comm. 2017).

Table 2.10 shows the final cost estimate of €0.3m in 2015 for measures related to security and defense.

Table 2.10 *Average annual costs related to security and defense, €m*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
Code of Conduct for explosive ordnance disposal [a]	D11 1A	0.1
Regulations on sonar use [a]	D11 1A	0.2
TOTALS		**0.3**

Sources: a) René Dekeling, pers. comm. 2017.

2.12 Government

The Dutch government is directly involved in policy work, management, monitoring of the North Sea environment and economic activities, and the improvement of the knowledge about- and further understanding of the North Sea environment. The costs involved include costs for policy preparation and coordination, subsidies and project outsourcing to research institutes, permit licensing, coastguard and inspection. In this section, the costs to the government are *only* presented in terms of the number of FTEs (Full Time Equivalent) involved in the management of the North Sea. Other costs (spendings on other costs than FTE) are not considered, but have been discussed in the other sections, where applicable. Two examples of such costs are water quality measures taken by water boards and environmental subsidies for the fisheries sector.

An important source of information is the Ecorys study carried out in 2007. In the Ecorys study, an estimate was made for 2005. The original table of that report has been updated in terms of the names and organisation of the relevant ministries, but the number of FTEs is assumed to be largely similar, although this assumption may result in a slight overestimate, since government organisations have seen significant cuts in staff since then. The total figure is expected to represent the number of FTEs in government concerned with marine environmental degradation (Table 2.11).

Table 2.11 *Estimated number of FTEs involved in North Sea management related work (2015)*

Government Body (total FTEs)	Sub-body	FTEs
Ministry of Infrastructure and Environment (160)	Directorate-General Transport	7
	Directorate-General Water	5
	Inspectorate for Transport, Public Works and Water Management	3
	North Sea Agency (RWS Zee & Delta)	72
	Specialist Services (i.e. RWS Water, Transport and the Environment)	66
	Other Services	7
Ministry of Economic Affairs (15)	Directorate Fisheries	6
	Directorate Nature	2
	Directorate Energy production	1
	State supervision of mines	6
Research institutes related to Ministry of Economic Affairs, Agriculture and Innovation (112)	Wageningen Economic Research	12
	Wageningen Marine Research	90
	Deltares	10
Ministry of Education, Culture and Science (39)	Netherlands Geological Survey	12
	Netherlands Institute for Ocean Research	25
	Netherlands Institute for Cultural Heritage	2
Ministry of Defence	Hydrographical service	10
Coast Guard		18
	Total	354

Source: Ecorys (2007), Rijkswaterstaat (2017).

An FTE is assumed to cost €100,000 per year. This number includes salary and other costs such as overhead, housing, etc. As a result the final costs for 2015 are estimated to be €35m.

2.13 Other activities and measures

Next to the measures that could be categorised in the 'activity-based sections' before, some other measures, mentioned in the Dutch MSFD Programme of Measures that could not be categorised in the 'activity-based sections' are described in this section. Most of these measures relate to (marine) litter, and for most of these, data on the cost is unavailable and requires further study.

The implementation of OSPAR List of threatened species and habitats
Sixteen species and 5 habitat types are relevant to the Dutch part of the North Sea. These species include porpoises, sharks, rays, and flat oysters. Plans for measures to restore the marine areas by preventing and remedying pollution and protecting the marine area against harmful effects of human activities are being worked out within the framework of the Habitats Directive, the Agreement on the Conservation of Small Cetaceans in the Baltic, North East Atlantic, Irish and North Seas (ASCOBANS) (porpoises) and the Common Fisheries Policy (porpoises, sharks and rays). In 2015, the Ministry of Economic Affairs commissioned the following research (Jeroen Vis pers. comm., 2017 & Ministerie van Economische Zaken, 2015):

- Harbour Porpoise Protection Plan: €250,000
- Bycatch of Harbour Porpoises: €50,000 (€200,000 for 4 years)
- MSFD Monitoring Program ('Informatiehuis marien'): €375,000
- Flat Oyster project: €100,000
- Sharks and rays: €30,000
- Protected areas: €100,000

The total cost of this measure is approximately €0.9m.

Clean Meuse/Clean Rivers initiative
A part of the litter that ends up on the beaches originates from the rivers. The Clean Meuse/Clean Rivers initiative was setup as a cooperation between volunteers, NGOs and the government to collect litter from riverbanks. The costs of this initiative consists of coordination of annual cleaning actions, collection of flood debris and litter transportation and processing. These costs are calculated to be €280,000-330,000 (Ecorys, 2014).

Plastic Cycle Chain Agreement
The Plastic Cycle Value Chain Agreement was signed in 2013 by 65 parties and is a voluntary, collaborative strategy with measures, signed and agreed upon by all signatories: private/societal parties and central government. The undersigned parties have the shared ambition to make definite steps towards creating a sustainable market for the entire production and consumption chain from raw materials to plastic products, the use of these products by companies and consumers, as well as the reuse of materials and products once they have been disposed of.

The following four sub-objectives are part of this agreement: 1) More sustainable products on the market (reduce, replace, redesign), 2) Widespread implementation of sustainable value chain earnings models (circular business models, renew), 3) More sustainable use (reduce, reuse) of products and materials and 4) More and improved recycling (renew, recycle: collection, sorting, processing and reuse of materials). For this measure, data on the costs in 2015 is unavailable and would require further study.

From Waste to Raw Material (VANG)
This measure relates to the Packaging Framework Agreement 2013-2022 (the collection and recycling of packaging by means of producer responsibility), the National litter policy (reward system for small PET bottles and cans etc.), the National litter policy (reward system for small PET bottles and cans etc.) and the National Waste Management Plan 2). For this measure, data on the costs in 2015 is unavailable and would require further study.

Reducing the use of plastic bags
For this measure, data on the costs in 2015 is unavailable and would require further study study.

Putting litter on the agenda of stakeholders and in education
This measure is described too broadly to calculate the costs and would require further study study.

Agenda-setting for water managers
This measure is described too broadly to calculate the costs and would require further study study.

Roll-out of Litter Collection Scheme
This measure is described too broadly to calculate the costs and would require further study study.

Promoting the reduction of balloons
This measure focuses on a reduction in the number of balloon releases and use of environment friendly alternative materials for ribbons: there is considerable opposition to, and legislation against, balloon releases, due to environmental concerns. The Dutch government is looking into ways to reduce the number of balloon releases. In 2015, a research was commissioned into environmentally friendly alternative materials for the (usually) plastic balloon ribbons. The cost of this research is €25,000. The additional costs of alternative materials for ribbons is not known and would require further study study (Ecorys, 2014)

Tax measures
This measure concerns fiscal incentives for environmentally friendly technologies (Environmental Investment Rebate (MIA) scheme/Arbitrary Depreciation of Environmental Investments scheme (Vamil).

In 2015, €93m was allocated for the Environmental Investment Rebate Scheme (MIA) and €438m for the Arbitrary Depreciation of Environmental Investments scheme (VAMIL) (RVO, 2017). Both of these measures are aimed at lowering the taxes for environment related investments. Thus, the cost of these measures can be attributed to the government. The investments relate to measures to lower the impact of emissions to the air and surface- and groundwater. If we assume that 5% would have an effect (which may be a lower estimate), the total amount on an annual basis would be €6.8m.

Table 2.12 shows the final minimum cost estimate of €8.9-9.8m in 2015 for other activities and measures not mentioned in the Dutch Programme of Measures.

Table 2.12 *Average annual costs related to other activities and measures, €m*

Measure	Dutch MSFD Program of Measures category type	Cost estimate
The implementation of OSPAR List of threatened species and habitats [L]	D1 1B	0.9
Clean Meuse/Clean Rivers initiative [a]	D10 1A	0.3
River basin oriented litter policy [b]	D10 1B	0.7-0.8
Voluntary reduction of micro plastics in cosmetics in the Netherlands [c]	D10 2B	<0.2-1
Plastic Cycle Chain Agreement [d]	D10 1B	N.A.
From Waste to Raw Material (VANG) [e]	D10 1B	N.A.
Reducing the use of plastic bags [f]	D10 1B	N.A.
Putting litter on the agenda of stakeholders and in education [g]	D10 2B	N.A.
Agenda-setting for water managers [h]	D10 2B	N.A.
Roll-out of Litter Collection Scheme [i]	D10 2B	N.A.
Promoting the reduction of balloons [j]	D10 2B	0.0 (25,000)
Tax measures [k]		6.8
TOTAL		**>8.9-9.8**

Sources; a) Ecorys (2014); b) Ecorys (2014); c) DEFRA (2017); d)/e)/f)/g)/h)/i) N.A.; j) Ecorys (2014); k) RVO (2017); L) Ministerie van Economische Zaken (2015).

2.14 Discussion

In this chapter, a wide variety of costs have been covered, with a variation in the accuracy or availability of these figures. In general, this report has applied the principle that it is better to underestimate a lower bound than to overestimate it. For example, the percentages used for land-based measures are, arguably, too conservative.

Another point to take into account, is that this report focusses on the current (2015) costs of measures taken to avoid environmental degradation in the Dutch part of the North Sea. 2015 has been chosen as the current year, since this is the most recent year where most of the necessary data are available. Because one particular year was chosen, and the costs for measures might be different over the years, the annual costs might also be different from year to year. However, because the costs calculated in this study are presented within a minimum and maximum value, it is safe to assume that the actual cost of degradation in the years before and after 2015 will also likely fall within this range.

For some measures, information about the costs was not available and needs further study. To get an idea about the magnitude of these costs in relation to the ones calculated in this study, together with Rijkswaterstaat, we have estimated the minimum-maximum cost ranges for each of those measures. As no data on these costs are available, these numbers are best guess cost estimates and should be treated as such. As a result, these numbers will (and should) not be included in the total cost estimate. The estimates of each measure are shown in the table below:

Table 2.13 shows the final minimum cost estimate of €8.9-9.8m in 2015 for other activities and measures not mentioned in the Dutch Programme of Measures.

Table 2.13

Type of measure where data on costs is unavailable	Potential cost estimate: €0-2m	Potential cost estimate: €2-5m	Potential cost estimate: €5-10m	Potential cost estimate: €10-100m	Potential cost estimate: €100+m
Avoiding turbidity	X				
Position of wind farms in less than optimal locations				X	
Restrictions of fisheries in coastal zone	X				
Minimising and phasing out of discards	X				
Deltaplan Agricultural Water Management				X	
Implementation of hull fouling guidelines		X			
Reduction of discharges	X				
Preventing and limiting industrial emissions					X
Reduction of environmental risks ensuing from major accidents				X	
Plastic cycle chain agreement	X				
VANG			X		
Reduce of plastic bags	X				
Total estimates	**€6-12m**	**€2-5m**	**€5-10m**	**€30-300m**	**€100+m**

If we would add up all the cost estimates mentioned in the table above, the total cost estimate would be at least €43-327m for the measures that have not been accounted for in the €513-1,667m mentioned in Table S.1. This means an underestimate of 3-64%. It is important to note that since it is not possible to provide an estimate for the measure ‘Preventing and limiting industrial emissions’ (the costs of which could be considerable), this cost range estimate should be considered as a lower bound.

The applicability of the cost data collected in this report needs to be considered. The insight into who is paying which costs to avoid marine environmental degradation can be useful when discussing affordability and/or the disproportionality of the costs of additional measures for the MSFD. The information provided on the current costs by sector can be used as the baseline to calculate the percentage change in the costs which is useful information to determine whether an increase in costs is disproportional or not. Other uses may not be practical. Using this cost data to infer benefits of new measures for use in a Social Cost Benefit Analysis (SCBA) would be difficult to justify. This is because the data does not refer to changes in costs which would result from new policies or measures and is therefore of limited use within a Social Cost Benefit Analysis.

3 The ecosystem services approach to determine the cost of degradation

3.1 Introduction

The second approach to calculate the cost of degradation is based on the Ecosystem Services Approach (ESS). In this chapter, insight is provided into the applicability of the ecosystem services approach methodology to calculate ecosystem benefits gained when Good Environmental Status is reached, in comparison to a Business as Usual scenario. By calculating the difference between these two values, insight is gained into the value of forgone ecosystem services benefits to be gained if/when GES is reached. This value equals the cost of degradation. In this chapter, several options to calculate the ESS are discussed and elaborated upon. Based on this, the preferred option is presented.

Ecosystem services[3] are defined as goods and services – benefits – that the ecosystem provides to human beings (MEA, 2005; EU com, 2011). In the first phase of the implementation of the MSFD in 2010/2011 five Member States (Ireland, Latvia, Sweden, Slovenia, United Kingdom) used some kind of ecosystem services type of approaches to analyse the cost of degradation (EU com, 2014).

The ecosystem services approach provides information on the value of the difference in ecosystem goods and services that would be provided in case of Good Environmental Status (GES), compared to the Business as Usual (BAU) scenario. To apply the ecosystem services approach, the additional ecosystem services when GES is achieved, have to be determined. The difference between BAU and GES can be seen as the benefits foregone, due to the insufficient condition of the marine environment of the North Sea in the Business as Usual scenario. To make this approach work, it is necessary to define ecosystem services, their characteristics, and the characteristics of the ecosystems that produce them. Based on this information, management, maintenance, restoration or evaluation of ecosystem services can be improved.

The following steps characterise the ecosystem services approach (EU com, 2011:36):

1. Define the status of two or more ecosystem states.
   – Define GES using the qualitative descriptors[4] (see Table 3.1).
   – Assess the environmental status in a Business As Usual (BAU) scenario.
2. Describe the gap, the differences in qualitative and, if possible, quantitative terms between the GES and the environmental status in the BAU scenario, i.e. the degraded state of the marine environment.
3. Describe the consequences to human well-being of degradation of the marine environment, either qualitatively, quantitatively or in monetary terms.

The first two steps are visualised in Figure 3.1. The target set for the status is the Good Environmental Status, with less negative anthropogenic effects to the marine environment. To compare the GES situation with the Business as Usual situation, indicators are needed. The EU translated a Good Environmental Status into 11 descriptors, with several criteria. As long as a target is set for these criteria, and as long as the current level of these criteria can be determined, the BAU-scenario and GES can be described in quantitative terms, making use of the GES criteria to assess the environmental status of the European seas.

Defined like this, it is possible to apply an ecosystem services type approach, without mentioning anything about ecosystem services (see for example Pakalniete et al., 2013 and Tuhkanen et al., 2015). But the objective of the ecosystem services approach is to calculate the costs of degradation in terms of the difference in the value of the ecosystem services between GES and BAU. So, this

[3] In this report the term ‘ecosystem services’ is used as shorthand for ‘ecosystem goods and services’.
[4] These are the descriptors as listed in Annex 1, list of elements in Table 1 Annex II and list of pressures in Table 2 Annex III in MSFD.

ecosystem services approach has to identify the ecosystem services and associated benefits which are potentially lost if GES is not reached. Step 2 of the ecosystem services approach can be made more specific by including ecosystem services as: 'Describe the gap, the differences in *ecosystem services,* qualitative and, if possible, quantitative terms between the GES and the environmental status in the BAU scenario, i.e. the degraded state of the marine environment' (EU com, 2011).

In the MSFD ecosystem services approach, the Good Environmental Status needs to be assessed against the 'business as usual' scenario, and not against the current state (EU com, 2011). This makes it necessary to know how the marine environment might evolve over time. The main elements to be considered in its development are 1) trends in marine uses and 2) implementation of existing and forthcoming policies that impact on the marine environment (except the MSFD). It is necessary to define one BAU scenario, consisting of the same descriptors and criteria used to describe the GES. The Dutch BAU situation can be found in Wienhoven et al. (2013). Currently, PBL Netherlands Environmental Assessment Agency is elaborating an updated BAU for the North Sea; the results of this new BAU are foreseen after finalisation of this report. For the economic analysis the BAU and GES have to be compared over a period of time, hence the sum of the services provided over that period have to be determined. A description of the ecosystem services provided currently (in a specific year) is being calculated by Statistics Netherlands.

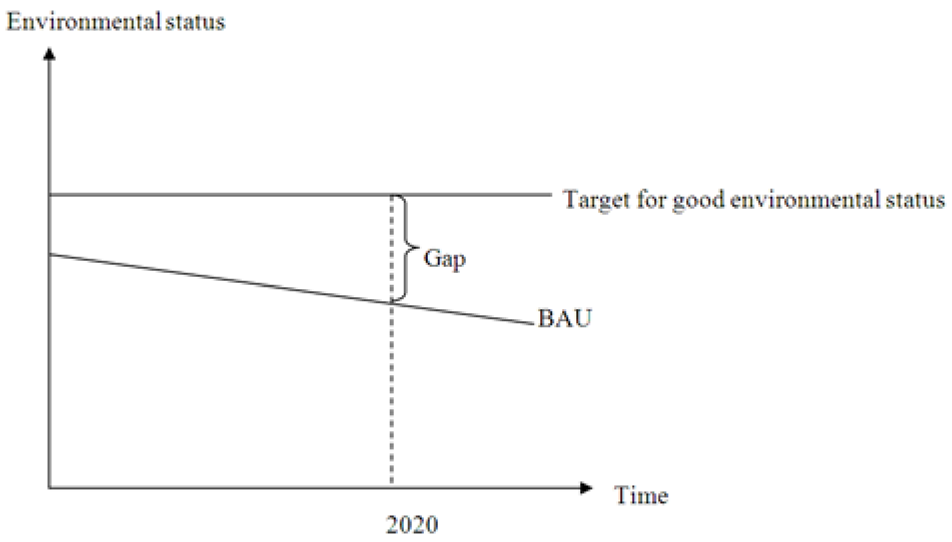

Figure 3.1 *The gap between Good Environmental Status and Business As Usual*[5]
Source: EU com (2011).

Reinhard et al. (2012) did the gap analysis for the Netherlands in 2011. In that study, the gap between the current situation and the Good Environmental Status is described. That study also identified policy measures to close the gap and presented an indication of the costs and benefits associated with these measures. Reinhard et al. (2012; Chapter 4) elaborated the link between changes in goals to all costs and benefits, but there wasn't an explicit focus on ecosystem services.

Section 3.2 focuses on recent literature relevant for the ecosystem services approach to determine the costs of degradation. In Section 3.3, the link between ecosystem services and human activities is made explicitly. The section thereafter, deals with the proposed categorisation of ecosystem services. Section 3.5 presents examples of the proposed method to perform an ecosystem services approach to determine the costs of degradation. The conclusions section is the last in this chapter.

[5] This Figure is a simplified illustration. In practice, the BAU does not change linearly, nor does it necessary decline (EU com, 2011).

3.2 Ecosystem services

Ecosystem services (ESS) are simply defined as 'the benefits humans derive from nature' (MEA, 2005). A more appropriate definition and classification of ecosystem services is needed to determine the costs of degradation (as the difference between the BAU and GES) via the ecosystem services approach. In this section, we focus on the question what ecosystem services are, and how ecosystem services are influenced and utilised by humans.

3.2.1 Ecosystem services in economic analysis

Ecosystem services are the aspects of ecosystems utilised (actively or passively) to produce human well-being (Fisher et al., 2009). TEEB (2010) defines services as 'actually conceptualisations (labels) of the 'useful things' ecosystems 'do' for people, directly and indirectly'. The key points are:
1) services must be ecological phenomena and 2) they do have to be utilised. Defined this way, ecosystem services include ecosystem organisation (e.g. stock and structure) as well as processes and/or functions if they are consumed or utilised by humanity either directly or indirectly (Fisher et al., 2009). The functions or processes become services if there are humans that benefit from them (Boyd and Banzhaf, 2007; Fisher et al., 2009). This way of thinking is illustrated in Figure 3.2. Two kinds of ecosystem services can be identified: intermediate ecosystem services (e.g. seabed formation) may be viewed as inputs into the biophysical production of final services. Humans benefit only from final ecosystem services, which can depend on intermediate services (in this example the value of sand mining depends on the characteristics of the seabed). To avoid double counting in economic valuation studies, this distinction between intermediate and final ecosystems services must be made. Only final services should be included in the valuation (see also Section 3.4). By focusing only on the final ecosystem services, the ecosystem services are the final outputs or products from ecosystems that are directly consumed, used (actively or passively) or otherwise enjoyed by people (EEA, 2015).

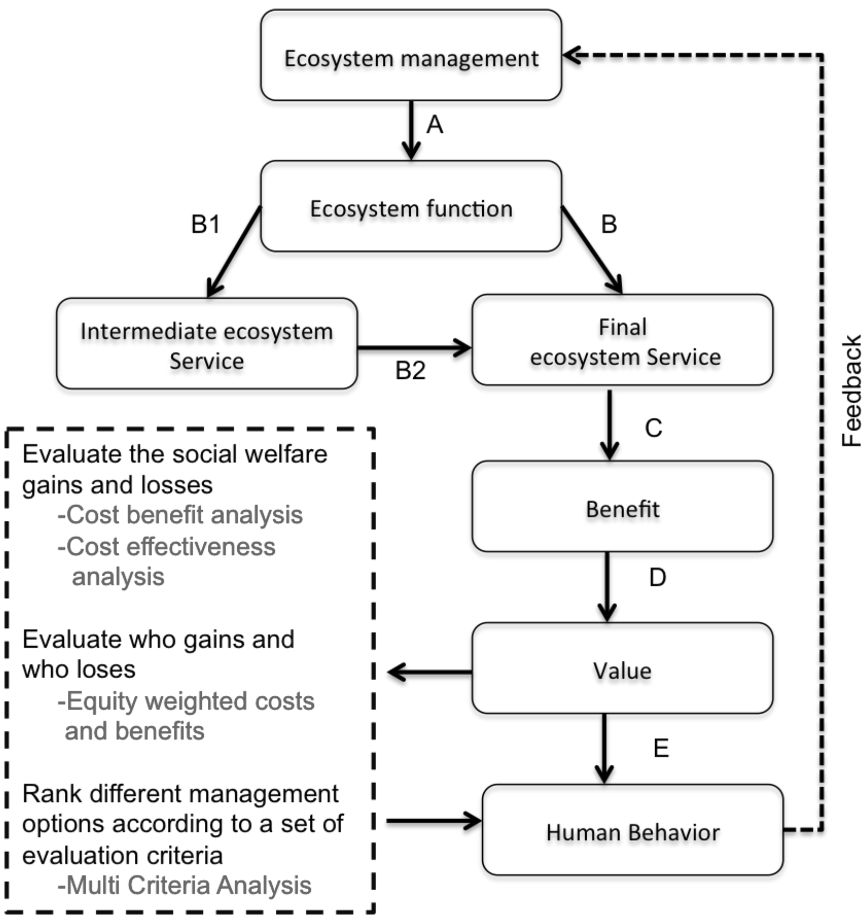

Figure 3.2 *The value of ecosystem services*
Source: Hanley et al. (2015); and DEFRA (2007).

Hanley et al. (2015) stress the need to identify and parameterise all linkages, between ecosystem state, ecosystem function, ecosystem service and the benefits and value of these services. The problem with applying this approach is related to the lack of scientific knowledge of key linkages in the valuation framework, a lack of relevant economic valuation studies and methodological problems in applying certain valuation methods to marine issues. Hence, it is important to define not only the relevant ecosystem(s), functions and services, but also the users and institutions.

How to proceed if the scientific bases is not complete? Reinhard et al. (2012) and Oinonen et al. (2016) applied a pragmatic approach to apply a cost-effectiveness analysis for measures of the MSFD. It is important that the analysis is transparent, pragmatic and useful. Oinonen et al. (2016) defined a pragmatic approach as an economically sound analysis carried out under very strict constraints with respect to data, knowledge, skills and time for completing the analysis. The cost and effect data were acquired via groups interviews following a set out procedure. This is more or less comparable with the method Reinhard et al. (2012) used in their CEA study for the Netherlands.

3.2.2 Ecosystem services as a co-product of human-derived and natural capital

A more holistic way of thinking about ecosystem services is by explicitly taking into account that humans and ecosystems are part of a socio-economic-ecological system, where the welfare of humans and the state of the natural world are co-dependent. Ecosystem services are defined in the context of their use by humans. This makes clear that besides natural capital (NC, the stock of physical assets in the environment on a specific point in time and space), human-derived capital (HDC, produced, human, social, cultural, financial) is necessary to create ecosystem services. Natural capital provides ecosystem services, which are related to benefits and human-derived capital is related to costs in a Cost Benefit Analysis (CBA). The quality of the human-derived capital affects the ecosystem services delivered (Jones et al., 2016). Pressure related GES descriptors such as GES 10, litter in the marine ecosystem, do not belong to the state of physical assets in the marine ecosystem.

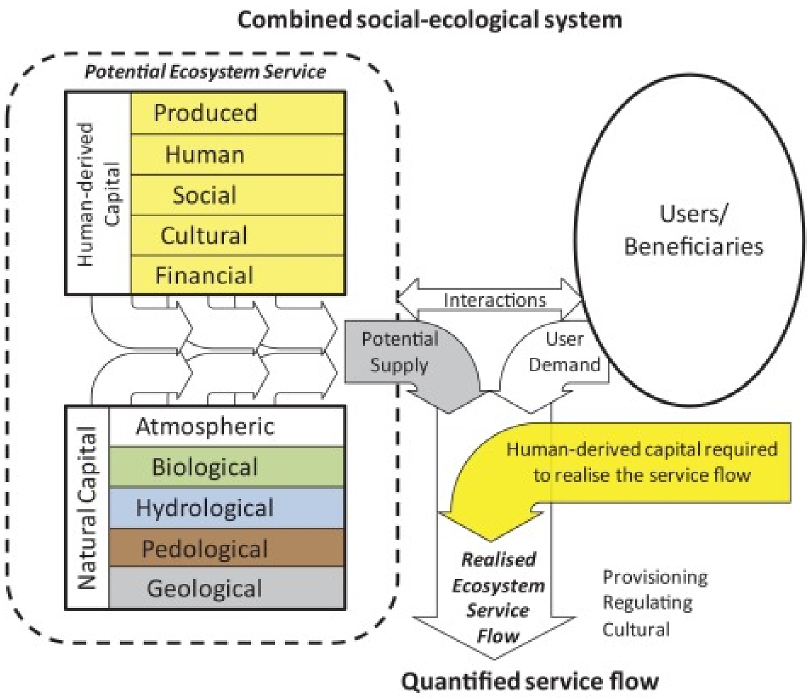

Figure 3.3 *Different forms of human-derived capital and natural capital co-produce potential ecosystem services*
Source: Jones et al. (2016).

Human-derived capital is necessary to deliver ecosystem services in three ways: 1) on the demand side, by shaping demand for the functions (making use of the functions): eating fish, etc.. This is also included in ‘the traditional ecosystem approach’, 2) as a direct input for the ecosystem itself (e.g. labour input for cultivating mussel beds) and 3) to enable the delivery of the ecosystem service (e.g. by making use of fishery boats, a camera or snorkelling equipment). This makes clear that human-derived capital is necessary for ecosystem services to exist.

The idea that human capital is necessary to receive benefits from ecosystems is recognised in the CICES classification for ecosystem services.[6] Ecosystem services are the link between ecosystems and things people benefit from (e.g. fish biomass), and are not the benefits themselves (the nutritional value of the fish biomass). This is because getting the benefit requires human input/actions (EEA, 2015). This distinction becomes relevant when ecosystem services are valued. The value of diving or (collecting) clams can, for instance, be increased by infrastructure investments in the accessibility of the seashore (without any change in the quantity of natural capital), see also Arcadis (2017). The complete value of fish in the sea cannot be calculated solely based on the quantity of natural capital; this will be elaborated in Section 3.3.3.

3.2.3 Biotic and abiotic ecosystem services

The benefits people get from ecosystems rely on biological and abiotic parts of the ecosystem. Both components contribute to providing ecosystem services, i.e. both biotic and abiotic outputs contribute to human welfare. In most definitions, ecosystem services are defined as being ecological in nature and provided by the living components of the ecosystem. The question whether abiotic components of the ecosystems has to be included into ecosystem services has been debated, because including is problematic (Hattam et al., 2015).

In a cost-benefit analysis, all welfare effects should be included. The provision of all biotic-ecosystem services is state dependent. If GES is reached, more services are provided with most likely a higher value. People can also benefit from the sea, independent of the state of the ecosystem. Examples are wind energy and transportation (to a certain extent). A change in water quality, or quantity of plastic in the sea will not affect the provision of wind energy. These activities (wind energy and transportation) are drivers for ecosystem change (degradation) (Böhnke-Henrichs et al., 2013). With respect to the aim of the MSFD, reaching GES, both components (biotic and abiotic) are relevant. The GES criteria of the MSFD are either indicators that describe pressures, or criteria that describe the environmental state (see Table 3.1).

CICES considers that the generation of ecosystem services must involve living organisms, so CICES only focuses on the biotic services. Abiotic environmental outputs (dredged sand, gravel and shells) are not services under this typology. As for example waste and toxicant dilution are mainly physical processes that rely on seawater volume and movement, these services are not considered as ecosystem service in CICES. For the MSFD, a broader definition of ecosystem services seems to be necessary to include all the extra goods and services people get from the GES of the marine ecosystem compared with the BAU. The MSFD criteria to assess GES recognise that abiotic factors influence the state of the marine ecosystem and thus the potential supply of services (Gómez et al., 2016).

[6] The Common International Classification of Ecosystem Services (CICES) is the ‘EU reference’ typology of all ecosystem services. (https://cices.eu)

Table 3.1 *Qualitative descriptors for determining Good Environmental Status in the MSFD*

MSFD descriptor	Short name	Classification
Biological diversity	D1	State
Non-indigenous species	D2	Pressure/ state
Commercially exploited fish and shellfish	D3	Pressure/ state
Marine food webs	D4	State
Human-induced eutrophication	D5	Pressure/ state
Sea floor integrity	D6	Pressure/ state
Hydrographical conditions	D7	Pressure/ state
Concentration of contaminants	D8	Pressure/ state
Contaminants in fish and other seafood	D9	Pressure
Marine litter	D10	Pressure
Energy, including underwater noise	D11	Pressure

Source: Berg et al. (2015).

The status is described by GES descriptors for biotic elements of the ecosystem (GES state descriptors are biotic). For example GES D1 (Table 3.1 links this short notation to the GES descriptors), describes the state of biological diversity. GES D1, D3, and D4 are the biodiversity-related descriptors. Many ecosystem services related to these GES descriptors can be separated, e.g. provisional services as seafood, regulation and maintenance functions as mediation of smell and visual impacts, and cultural services as fishing for leisure (see for a more complete overview Tables 3.2, 3.3 and 3.4, where the biotic services are presented at the left hand side). There are also pressure criteria related to abiotic elements of the ecosystem. For example GES D8, contaminants. The abiotic criteria are ‘concentrations are below standards set by national and international legislation’. Most of these descriptors make use of biotic criteria, as well as the effect of the abiotic factor on the ecosystem. The question is whether it is necessary to expand the definition of ecosystem services, by including abiotic services of ecosystems as well. Are the abiotic GES descriptors, and the abiotic services regarded as the environmental condition necessary for productive ecosystems, or are they part of the ecosystem? If the decline in abiotic output is regarded only as an element of the costs of reaching GES, it is not an ecosystem service and should not be included in the ecosystem services approach to compute costs of degradation. However on the one hand, since several descriptors are directly related to abiotic services (and not to biotic services), it is suggested to include both kind of services (biotic and abiotic), to cover the entire MSFD in the analysis. On the other hand, if D1 ‘biological diversity’ and D4 ‘Marine Foodwebs’ are regarded as the ultimate goal of the MSFD and that the other descriptors are supporting these two descriptors (D1 and D4), than only biotic ecosystem services should be taken into account.

3.3 Ecosystem-based approach concepts

This section describes the framework applied to describe the impact of changes in the environmental status of the North Sea (in terms of ecosystem services) on humans. This framework links the intended and unintended changes in the Good Environmental Status and the associated GES-criteria to ecosystem services. One of the requirements of the MSFD is that Member States shall apply an ecosystem-based approach to assess the state of their marine area. Within this section we will describe different frameworks to apply an ecosystem-based approach. These frameworks incorporate the connection between human and ecological issues. Performance indicators are identified and organised to facilitate different regulatory needs. The DPSIR framework, the EBM-DPSER framework, and a model that fits ecosystem services in a socio-economic system are presented.

3.3.1 DPSIR in initial assessment MSFD

For the initial assessment of the MSFD, the DPSIR framework as developed by the EEA is used to develop indicators and targets needed to assess whether GES is reached (Boon et al., 2011). According to the DPSIR framework, see Figure 3.4, drivers are the cause of change in the ecosystem. The framework presents a chain of causal links starting with ‘Driving forces’ (economic sectors, human activities in marine waters) through direct and indirect 'Pressures' on the marine environment (emissions, disturbance) to 'States' (physical, chemical and biological) and 'Impacts' on society, human health and ecosystem services, eventually leading to social (political) 'Responses' (prioritisation, target-setting, indicators, eventually resulting in additional/new measures), which may be linked back to Drivers, Pressures, States and Impacts. The EEA (2015) indicates that the relationships between the drivers, pressures, states and impacts should be made as clear as possible, and that indicators can be found at each 'level': pressure, state or impact.

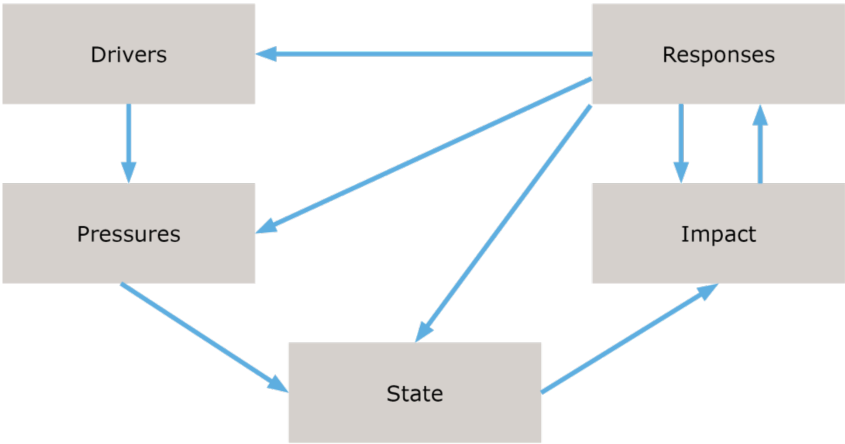

Figure 3.4 *The DPSIR framework*

Drivers and pressures will affect the state of the marine ecosystem. It is necessary to know how a pressure affects the state of the ecosystem. An impact on the state of the ecosystem can lead to changes in ecosystem functioning (on the ecological side) and in the subsequent supply of ecosystem services and abiotic outputs. The ecosystem services are not included in the DPSIR framework used for the initial assessment. However, they can be used to describe the impacts of pressures on the state of the marine environment.

Two GES descriptors represent the most important marine ecosystem features of concern, favourable or threatened, e.g.: D1 'biological diversity', and D4 'marine food webs'. These are the state descriptors. Another part of the descriptors represents human drivers and the pressures on the ecosystems, the pressure descriptors, see Table 3.1 for an overview (Berg et al., 2015). Based on the DPSIR framework, the criteria for assessing GES in the Netherlands were developed (Boon et al., 2011). An important reason why the concept of ecosystem goods and services is not incorporated as integral part of the Marine Strategy Framework Directive, is due to the fact that at the time the Directive was written, around the year 2000, the concept of ecosystem goods and services was not yet as broadly used and accepted in international public policies as now, 17 years later.

In the DPSIR Framework, an explicit link to ecosystem services is missing. This framework doesn't adequately capture the full range of ecosystem services (the interaction between humans and the environment), due to its focus on pressures, e.g. on the negative impacts of human activities upon the ecosystem. So, the current DPSIR framework cannot be used to analyse changes in ecosystem services (Kelble et al., 2013). What is needed to make this possible is knowing the ecosystem components that potentially contribute to the supply of a service.

3.3.2 EBM-DPSER framework: ecosystem services integrated in the DPSIR framework

A more holistic DPSIR model, including ecosystem-based management (EBM) and ecosystem services is developed by Kelble et al. (2013). Ecosystem services reflect societal goals, values, desires and benefits. The links between the intended and unintended changes in the Good Environmental Status, the associated GES-criteria and ecosystem services are necessary to apply the ecosystem services approach. This is the reason that the EBM-DPSER framework is relevant to determine the costs of degradation. As in the DPSIR model, this model considers drivers to be the ultimate cause of change in the ecosystem. Drivers can be any combination of biophysical, human, and institutional actions or processes. This leads to pressures on the ecosystem; the physical, chemical, and biological mechanisms that are the proximal causes of change in the ecosystem. Due to these pressures, the marine ecosystem changes into a less than Good Environmental Status. The EBM-DPSIR framework replaces the impact 'module' with the ecosystem services 'module', see Figure 3.5. Due to a change in the marine ecosystem, the provision of the ecosystem services will change as well in this EBM-DPSER framework. The current MSFD ecosystem services approaches determine the cost of degradation mainly on the supply side of the marine ecosystem: what is the capacity of a specific state to deliver services to the human system?

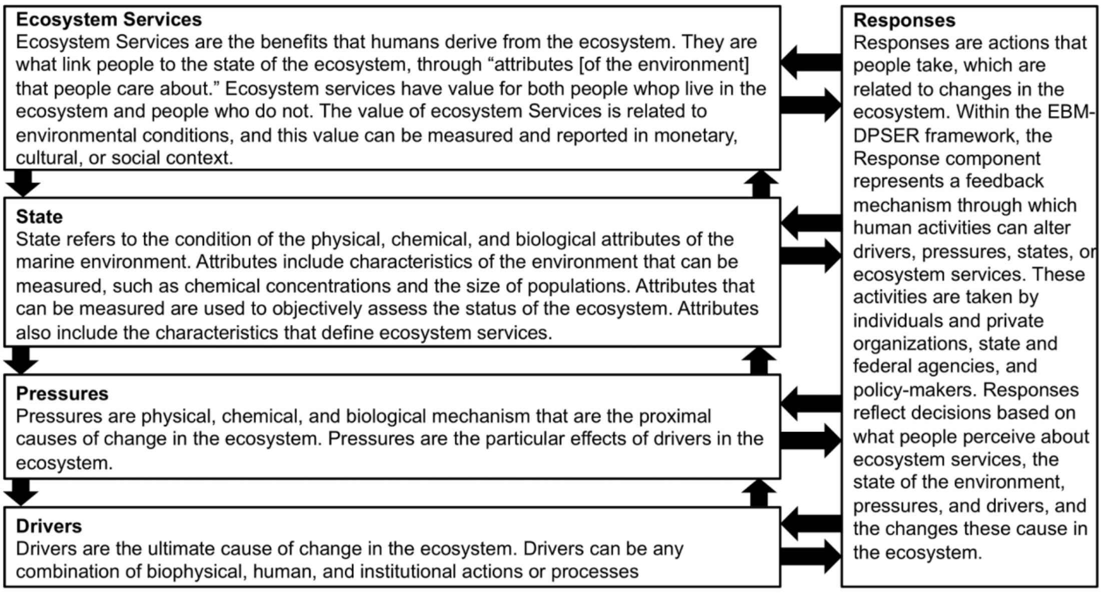

Figure 3.5 *EBM-DPSER conceptual model: ecosystem services integrated in the DPSIR framework*
Source: Kelble et al. (2013)

The EBM-DPSER framework is flexible and can accommodate alternative definitions and classifications of ecosystem services. To determine the costs of degradation with this framework, the definitions and classification of ecosystem services have to be appropriate and the link between the ecosystem's state and the provided ecosystem services has to be known (E.g. Which ecosystem state provides which services, and which pressures impact the states and the potential underlying ecosystem services). In ecosystem approach studies to determine the costs of degradation studies (Pakalniete et al., 2013; Tuhkanen et al., 2015) the link between the ecosystem state and the provided services is not known.

3.3.3 Ecosystem services in a socio-economic system

To identify the links between the socio-economic system and the ecosystem, the project Aquacross developed the concept presented in Figure 3.6. This figure illustrates the flows to be considered, in order to understand the causal links between biodiversity, ecosystem functions and services. The capacity to deliver services is directly linked to the ecosystem (e.g. maximum sustainable yield), while the demand of ecosystem services (e.g. the fish bought) is the entry point to the socio-economic system, the human system. Demand differs from benefits: benefits are generated by Ecosystem Services in combination with other forms of capital (e.g. to catch fish, natural and human capital (e.g. ship) is needed). Benefits have a direct impact on human welfare (Gómez et al., 2016).

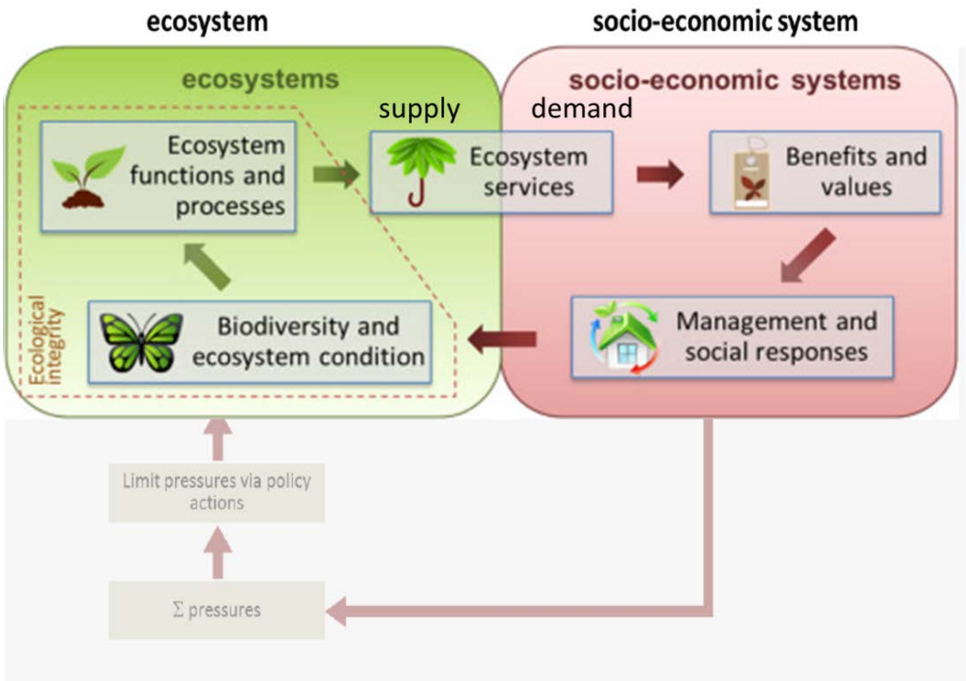

Figure 3.6 *Social-ecological system*
Source: Gómez et al. (2016:104) and Liquete et al. (2016).

In order to understand the role of the GES criteria, it is necessary to identify on which part of the ecosystem the pressures (and the relevant GES criteria) have an effect and to which part of the ecosystem the state GES descriptors are linked and how this part of the ecosystem provides the services. An approach could be to consider more parts together, for example on a regional scale (Gómez et al., 2016). An example of a spatially resolve pressure-based approach to evaluate the combined pressure of human activities is given in Goodsir et al. (2015). In contrast to the DPSIR framework wherein the pressures are assessed independently, this method assess the combined impact of multiple activities (e.g. cumulative impacts), by both linking human activities to specific pressures and by applying a measure of the sensitivity of the ecosystem to those pressures.

The concept presented in Figure 3.6 makes clear that a change in ecosystem state can lead to a change in the supply of services (sustainable state of fish), but not automatically in a change in the demand for services (demand for fish). The demand for ESS, including the use of abiotic natural capital, or the use of ecosystem 'space' for economic activities, can affect the supply (value) of ecosystem services (Gómez et al., 2016). For instance, in case meat is taxed to incorporate its CO_2 emissions in the price, meat will be (partly) substituted by fish, and the fish price will rise. In that case the value of the ecosystem service is increased, while the total catch does not have changed.
This concept also clarifies that demand and actual use of services can be decoupled from the state of the ecosystem, as they are a clear outcome of social processes. For example, a study of recreational clam digging found that most activity occurred at easily accessible sites (parking facilities in the neighbourhood) even though more valuable stocks were present in other (less accessible) locations (Gómez et al., 2016).

3.4 Ecosystem services categorisation

Now ecosystem services are defined, they can be categorised to enable the determination of the costs of degradation as the difference between the BAU and GES state via the ecosystem services approach. The question that will be answered in this section is: How can the ecosystem services provided by the North Sea be classified to enable easy and coherent calculation of the cost of degradation?

There have been several efforts to classify ecosystem services. There is no single, agreed method to categorise ecosystem services. One of the first attempts to create an ecosystem service classification is the Millennium Ecosystem Assessment framework (MEA 2005), where ecosystem services have been classified into provisioning, regulating, cultural, and supporting services. Other classifications are more suitable for assessing the value of ecosystem services in a changing environment where focus is on marginal changes; e.g. MAES (Maes et al., 2013) and UK NEA, or on accounting (e.g. CICES). The MEA-classification is elaborated by CICES to consider all potential ecosystem services and to avoid double-counting the value of these services. Several studies have elaborated upon the quantification and valuation of ecosystem services, some of them focussed on the marine environment; e.g. CICES, OpenNess (2014) and Atlas Natuurlijk Kapitaal (de Knegt, 2014).

The most recent CICES classification of marine ecosystem services, based on the actual use of the sea, is presented in Tables 3.2, 3.3 and 3.4 for respectively provisioning, for regulating and maintenance, and for cultural ecosystem services at present. Again, it is important to realise that this CICES classification (based on the actual use of the sea) is only related to the marine biota, abiotic processes are not included.[7] The CICES classification is broadened by Gómez et al. (2016), as discussed in Section 3.2.3, by considering biotic and abiotic dimensions. In Table 3.2, 3.3, 3.4 abiotic processes are included as well (at the right hand side).

Table 3.2 *Ecosystem services, considering both biotic and abiotic dimensions, for the provisioning services category following CICES classification (adapted from Gómez et al., 2016, Hattam et al., 2015)*

Ecosystem services		Abiotic outputs from ecosystems	
Provisioning			Abiotic provisioning
Division	Group and examples	Group and examples	Division
Food provision	**Biomass** Wild captured seafood; Farmed seafood	**Mineral** Marine salt	**Nutritional abiotic substances**
	Water Surface of groundwater for drinking purposes	**Non-mineral** Sunlight	
Materials	**Biomass** Fibers and other raw materials genetic resources (DNA) medicinal resources	**Metallic** Metal ores	**Abiotic materials**
	Water Surface or groundwater for non-drinking purposes	**Non-metallic** Minerals Sand/ gravel	
Energy	**Biomass**	**Renewable abiotic energy** Wind Waves	**Energy**
		Non-renewable abiotic energy resources Oil and gas	

As is explained in Section 3.2.1, to avoid double counting in an economic-valuation approach, only final services should be included. In Figure 3.4, the different types of ecosystem services are categorised as final or intermediate services. As in the CICES overview, in the overview of Gómez et al. (2016), intermediate regulating services are included. As these services are valued already in the provisional and cultural services, these will not be taken into account in the ecosystem services analysis of the cost of degradation. In Table 3.3, for each intermediate biotic ecosystem service is indicated whether it is a final or an intermediate service.

[7] In the 'Digitale atlas natuurlijk kapitaal', DANK (de Knegt et al., 2014), abiotic services are taken into account. This system is based on the CICES classification (http://www.atlasnatuurlijkkapitaal.nl/web/ank/natuurlijk-kapitaal). Abiotic ecosystem outputs are not included in the CICES classification, but CICES made a suggestion about how ecosystem outputs independent of living processes might be handled in a way that is consistent with their classification (http://cices.eu/cices-structure/).

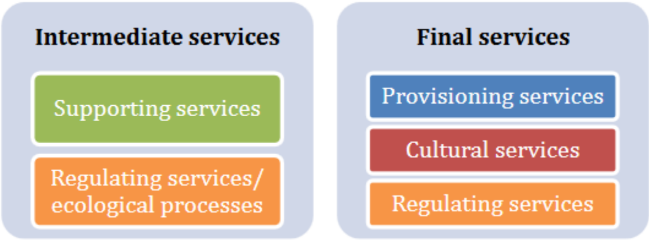

Figure 3.7 *Classification of ecosystem services as final of intermediate service (Mace and Bateman, 2011)*

Hattam et al. (2015) made a classification of ecosystem services based on de Groot et al. (2010) and Böhnke-Henrichs et al. (2013). In this classification, there is no separation between biotic and abiotic services. In this study however, it is assumed that the services Coastal erosion prevention, Disturbance prevention or moderation and regulation of water flows are more regulated by the abiotic structures than to the biotic ecosystem. Waste treatment is related to both dimensions.

Table 3.3 *Ecosystem services, considering both biotic and abiotic dimensions, for the regulating services category following CICES classification a)*

Ecosystem services		Abiotic outputs from ecosystems	
regulating and maintenance			regulating and maintenance by abiotic structures
Division	Group and examples	Group and examples	Division
Mediation of water, toxics and other nuisances	**Mediation by biota: a final service** Waste treatment	**By natural chemical and physical processes: a final service** Waste treatment	**Mediation of water, toxics and other nuisances**
	Mediation by ecosystems: Combination of biotic and abiotic factors		
Mediation of flows	**Mass flows: final service** Air purification Climate regulation	**By solid (mass), liquid and gaseous (air) flows: a final service?** Coastal erosion prevention Disturbance prevention or moderation Regulation of water flows	**Mediation of flows by natural abiotic structures**
Maintenance of physical, chemical, biological conditions	**Lifecycle maintenance, habitat and gene pool protection: an intermediate (and not a final service)** Biological control Gene pool protection	**By natural chemical and physical processes: an intermediate (and not a final service)** Sea breezes	**Maintenance of physical, chemical, abiotic conditions**

a) Most of these services are intermediate services.

Source: Gómez et al. (2016), Hattam et al. (2015).

Table 3.4 *Ecosystem services, considering both biotic and abiotic dimensions, for the* *<u>cultural services</u>* *category following CICES classification*

Ecosystem services		Abiotic outputs from ecosystems	
Cultural		**Cultural settings dependent on aquatic abiotic structures**	
Division	**Group and examples**	**Group and examples**	**Division**
Physical and intellectual interactions with biota, ecosystems, and seascapes (environmental settings)	**Physical and experiential interactions** Leisure, recreation and tourism		**Physical and intellectual interactions with land-/ seascapes (physical settings)**
	Experiential use of biota and seascapes; physical use of seascapes in different environmental settings	Experiential use of seascapes; physical use of seascapes in different physical settings caves	
	By physical and experiential interactions or intellectual and representational interactions		
	Intellectual and representational interactions information for cognitive development (scientific, education) cultural heritage aesthetic experience inspiration for culture, art and design		
Spiritual, symbolic and other interactions with biota, ecosystems, and seascapes (environmental settings)	**Spiritual and/ or emblematic** Spiritual experience; sacred rocks Cultural diversity		**Spiritual, symbolic and other interactions with land-/ seascapes (physical settings)**
	Other cultural outputs Existence; bequest		

Source: Gómez et al. (2016), Hattam et al. (2015).

In Hasler et al. (2016) ecosystem services are linked to the GES descriptors for the cultural service 'recreation' and, for the provisional service 'wild fish for food' (See Table 3.6). The value of biotic ecosystem services depends on the state of the ecosystem. This can also be valid for abiotic outputs, for example in case of the recreational service 'shipping on sea'. Marine litter (GES 10) will affect the value of this service. Most of the other abiotic outputs from ecosystems are mainly independent on the state of the ecosystem, but an increase in output can imply an increased pressure on the ecosystem, and vice versa.

The concept of ecosystem services is appealing, because it offers a comprehensive methodology that links explicitly ecological concepts with that of economists. Hereinabove is shown that several definitions of ecosystems and ecosystem services can be used, depending on the study's objective. Some are more ecological focussed and others have a more economic focus. The range of different ecosystem services studies, ranked from pure ecological studies (on the left-hand side), proceeding to the right the methodology contains more economic elements, towards pure economic studies (on the right-hand side) is presented in Table 3.5. On the right-hand-side the cost benefit analysis can be found (which includes also services that are not traded on the market). This Table 3.5 also gives an overview of different methods to describe the costs of degradation based on ecosystem services and examples of studies. The rows of Table 3.5 contain the relevant building blocks for the computation of the costs of degradation as well as an inventory of elements discussed in previous sections related to the distinguished types of ecosystem services studies (e.g. whether abiotic services are included and whether intermediate or only final services are included). The information in Table 3.5 provides a comprehensive overview of the definitions applied and the information included in the different types of studies.

The distinction between an ecosystem services approach and CBA is that the latter includes the costs of measures to reach the GES target, while the former focusses on the benefits of the measures taken to reach GES.

Table 3.5 *An overview of different types of ecosystem services related studies, with some examples. The studies are ranked from pure ecological studies (on the left hand side) towards pure economic studies (on the right-hand side). The characteristics of the ecosystem services applied in these types of studies are presented in the rows of the lower part of this table*

	Biodiversity and ecosystem state	Ecosystem functions and processes	Ecosystem services	Value of ecosystem services at time t	Comparing the value of ecosystem services in different states	Comparing the value of ecosystem services in different states
Examples only biotic services	GES descriptors 1, 2, 3 and 4.		MEA, 2005; CICES, TEEB		MKBA werkwijzer natuur. Most monetary valuation studies in Table 3.6.	
Examples biotic and a-biotic services	GES descriptors 5, 6 and 7.		CICES$^+$ (Aquacross), DANK	DANK, MSFD-accounting (CBS), MSFD-NAMWA (CBS),	Costs of degradation	CBA
Elements included in the studies						
human costs for provision					human costs for provision	human costs for provision
Costs for measures included						All welfare effects, incl. costs for measures
Only supply of ESS or supply & demand			Supply	Demand	Demand	Demand
Ecosystem services included			Final services	Final services	Final services	Final services
			Intermediate services			
System taken into account	Ecosystem	Ecosystem	Ecosystem and socio-economic system	Socio-economic system, inclusive ecosystem services	Socio-economic system, inclusive ecosystem services	Socio-economic system, inclusive ecosystem services

To compute the costs of degradation based on the ecosystem services approach, the ecosystem services to be included in the analysis have to be agreed upon. The CICES classification is developed in EU supported projects and widely used. CICES focuses on biotic ecosystems and does not include abiotic outputs, while they are an important part of the GES descriptors. Another choice is whether ecosystem services are described solely on the biotic components or that demand for ecosystem services is included in the analysis. Based on the different options, a spectrum of ecosystem services approaches is presented, from the pure biological methods to the (economic) cost-benefit analysis.

3.5 Examples of studies including ecosystem services for the MSFD

In this section, some examples of (ex ante) cost benefit analysis are presented and analysed to show which elements of the CBA are also included in cost of degradation studies, based on a welfare approach, to illustrate the difference between both methods.

3.5.1 Example of Dutch cost-benefit analysis framework for MSFD

Reinhard et al. (2012) identified a gap between the GES and BAU for the following GES descriptors: GES 1, 3, 4 and 6, GES2: non indigenous species, GES 5: Eutrophication, and GES 10: Marine litter. Due to lots of overlap between the GES 1, 3, 4 and 6, these descriptors are taken together as GES1. For the combined GES1 additional measures could be taken. In the CBA part of the Reinhard et al. (2012) study, the welfare effects were related to changes in the GES descriptors. In Figure 3.8 all possible welfare effects, costs and benefits related to measures for GES1 are visualised.

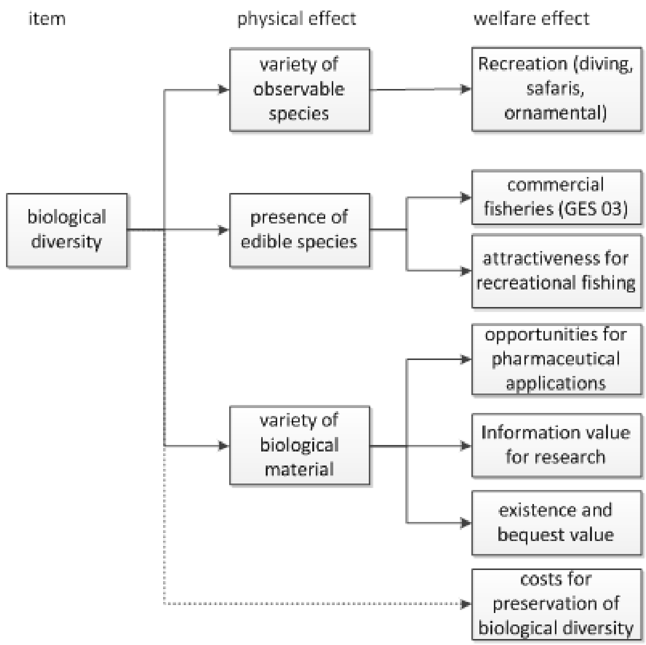

Figure 3.8 *Welfare effects of changes in GES descriptor 1*
Source: Reinhard et al. (2012).

All the positively valued welfare effects (all welfare effects, except the costs for preservation of biological diversity) in Figure 3.8 are ecosystem services. The welfare effects are quantified (in million € per year) by applying assumptions and a bandwidth.

The welfare effects of the measure ‘collection of litter along Dutch rivers’ are presented in Table 3.6. Money spent on the measure itself is not included in the ecosystem services approach. In this case the benefit ‘less damage reduction in marine use functions’ is included in the welfare effects, but this is not the result of a change in one of the ecosystem services (and not included in ESS). The change in quality of the marine ecosystem is not quantified.

Table 3.6 *Welfare effects of changes in GES descriptor 10, presented as the costs and benefits of litter collection by Rijkswaterstaat (RWS, a government agency responsible for the design, construction, management and maintenance of the main infrastructure facilities in the Netherlands) along the banks of the rivers Rhine, Waal and IJssel, 2014 prices). Source: Wienhoven and Verheijen (2014)*

	Net present value period 2015-2020
Costs	
Administrative costs RWS	k€ 220
Execution costs RWS	k€ 510-910
Coordination costs project partners	k€ 2710
Benefits	
Savings on current litter collection costs	++
Avoided (rest) damage nature, agriculture, recreation	+
Increased experience value rural area	+
Quality marine ecosystem	0/++
Damage reduction marine use functions	k€ 650-980
Spill-over effect public space	0/+
Indirect effect business climate municipalities	0/+
Total costs	K€ 3340-3840
Total benefits	K€ 650-980 +?
Balance	?!!

* 0/+ reflects insecurity about whether the effect will arise or not.

** ?!! reflects that it is not possible to quantify the cost benefit balance.

3.5.2 Studies assessing welfare effects of reaching GES

An overview of studies assessing welfare effects of changes in the marine ecosystem state is given in Table 3.7. For each study is indicated to which GES descriptor the study is related. Three studies focus explicitly on all main concerns with respect to reaching GES in a country, the Latvian study(Pakalniete et al., 2013), the Estonian study (Tuhkanen et al., 2015) and the UK study (HMGovernment, 2012a; 2012b). These studies are explained in a bit more detail in this paragraph. The other valuation studies carried out are related to achieving the GES status for one or more GES descriptors.

Table 3.7 *Overview of marine valuation studies, based upon Torres and Hanley (2016) and Hasler et al. (2016)*

Authors	Focus	Area	Ecosystem services	GES descriptors
Ahtainen and Vanhatalo (2012)	Reducing eutrophication	European sea areas	Non consumptive direct use value Non-use value	D5. Eutrophication is minimised
Ahtiainen et al. (2014)	benefits of reduced eutrophication	the Baltic Sea (international, 9 countries)	cultural (recreation, non-use benefits)	D5. Eutrophication is minimised, D1. Biodiversity is maintained
Börger et al (2014)	Conservation of offshore sandbank (UK part of Doggersbank). Diversity of species. Invsive species.	UK	Non-use values	D1. Biodiversity is maintained,
Carlsson, Kataria and Lampi (2010)	benefits from improved marine environment (endangered species, oil surveillance, fishing jobs, fish stocks)	the Baltic Sea (national, Sweden)	provisioning and cultural services (food, recreation, non-use benefits)	D1. Biodiversity is maintained, D3. The population of commercial fish species is healthy

Authors	Focus	Area	Ecosystem services	GES descriptors
Eggert and Olsson (2009)	benefits of improved water quality	coastal waters of Skagerrak and Kattegat (regional, Sweden)	provisioning and cultural services (food, recreation, non-use benefits)	D1. Biodiversity is maintained, D3. The population of commercial fish species is healthy
Gren (2013)	Value of filtering of nutrients in the coastal zone in the Baltic	The Baltic Sea, divided into 7 sea regions (international, 9 countries)	regulating services (eutrophication mitigation)	D5. Eutrophication is minimised
Jobsvogt (2014a)	Additional MPA's in Scottish deep-sea. Deep sea organisms	Scotland	Option value Existence value	D1. Biodiversity is maintained,
Jobsvogt (2014b)	Additional MPA's	UK (divers and anglers)	Non consumptive direct use value Option value Non-use value	D1. Biodiversity is maintained,
Kosenius (2010)	benefits of reduced eutrophication	the Gulf of Finland (national, Finland)	cultural services (recreation, non-use benefits)	D5. Eutrophication is minimised, D1. Biodiversity is maintained
Kosenius and Ollikainen (2015)	benefits of changes in coastal habitats (healthy vegetation, pristine areas, fish stocks)	Finnish-Swedish archipelago and Lithuanian coast (international, 3 countries)	provisioning and cultural services (food, recreation, non-use benefits)	D1. Biodiversity is maintained, D3. The population of commercial fish species is healthy, D5. Eutrophication is minimised
Kulmala et al. (2012)	benefits of ecosystem services provided by Baltic salmon	the Baltic Sea (international, 4 countries)	provisioning and cultural services (food, recreation)	D1. Biodiversity is maintained, D3. The population of commercial fish species is healthy
Lewis et al. (2013)	values of marine cultural ecosystem services (algal blooms, species visibility and population, fisheries catch and profitability)	Gdynia (regional, Poland)	cultural services (recreation, aesthetic benefits, non-use benefits)	D1. Biodiversity is maintained, D3. The population of commercial fish species is healthy, D5. Eutrophication is minimised
McVittie and Morran (2010)	Estimation of the non-market benefits from conservation of ecosystem goods and services resulting from implementation of proposed MCZs	UK	Consumptive directe use Indirect use Non-consumptive direct use Existence value Cultural value	
Nunes and van den Bergh (2004)	Invasive marine species	Netherlands		D2. Invasive marine species
Nunes et al (2009)	Alternative shellfishery policy	Netherlands	Consumptive direct use Non-consumptive direct use Non-use value	
Östberg et al. (2013)	benefits from improved coastal environment (water quality, cyanobacterial blooms, noise, littering)	the Eight Fjords area, Skagerrak and Himmerfjärden, the Baltic Proper (2 regions in Sweden)	cultural services (recreation, non-use benefits	D5. Eutrophication is minimised, D10. Marine litter does not cause harm

Authors	Focus	Area	Ecosystem services	GES descriptors
Pakalniete et al. (2013)	Invasive marine species	Latvia		D1. Biodiversity is maintained D2. Invasive marine species Water quality (algae)
Ruiz-Frau et al (2013)	Provision of recreational services	Wales	Non-consumptive direct use	
Tuhkanen et al. (2015)	Invasive marine species	Estonia		D2. Invasive marine species D5. Eutrophication is minimised Risk on oil and chemical spills
HMGovernment (2012b)	Cost of degradation in 2020	UK	Provisioning services Regulating services Cultural services	D1. Bird D3. Commercial fish D6 Seafloor integrity D10. Marine litter
Wattage et al (2011)	Conservation of deep-sea corals	Ireland	Option value Existence value Bequest value	D1. Birds

A study for Latvia and a study for Estonia were carried out to estimate the total welfare effects of reaching GES. These studies were part of the GES-REG project (Good Environmental Status through REGional coordination and capacity building) and co-funded by the EU (Interreg). Pakalniete et al., 2013 the Latvian study, apply a choice experiment to value the differences between three scenarios; 'no additional action', BAU and, GES of the marine ecosystem. The valued attributes were the reduced number of native species (biodiversity), water quality for recreation at sea (water clarity and, amount of algae washed ashore) and establishment of new harmful alien species. The share of the population with a willingness to pay (WTP) of zero is 42.7% for the GES scenario. The mean WTP of the rest of the population is almost 10 LVL, the mean WTP op the whole population to reach GES is 5.7 LVL per person per year (€4 per person per year), compared to the current state of the environment. The extra WTP for reaching the GES in comparison with the WTP for reaching the BAU scenario is much smaller, about €1.20 per person per year.

Tuhkanen et al. (2015) estimated the economic benefits of achieving GES levels in the Estonian study in terms of reduction of the following three main concerns with respect to the Estonian waters: i) the risk of oil and chemical spills (cases of large-scale pollution of marine waters and probability that pollution reaches the shore), ii) water quality (nutrient pollution) and, iii) invasive species. An average Estonian household would be willing to pay €65 per year to reach GES in the Estonian Marine Waters, 26% can be attributed to large-scale oil spills, 30% to the reduction in the probability that in the case of a spill pollution will reach the shore, 27% to the improvement in water quality and 16% to the reduction of the risk of introducing new non-indigenous species.

It is remarkable that the welfare effect of a change in environmental state is valued, and that the concept of ecosystem services is not mentioned in these two studies. CE (choice experiment) is a good method to estimate the value of a multi-attribute environmental good, as the state of the environment is. With this method, based on the preferences to the proposed environmental improvements, individual welfare changes can be derived. These can be used to characterise national benefits from the valued marine environmental improvement.

Another country applying an ecosystem services approach to determine the cost of degradation was the UK (HMGovernment, 2012a; 2012b). To identify the changes in the provision of ecosystem services between the BAU scenario and achievement of GES the following steps were taken:

- Identification of the ecosystem components that provide these final ecosystem services and the key pressures that impact on them.

- Experts in Defra, JNCC and Cefas assessed whether there is any degradation in the ecosystem components, or significant changes in the impact or the pressures, when comparing the BAU scenario with the achievement of GES.

Final groups of ecosystem services were identified, and related to the relevant ecosystem components or pressures. For the relevant components and pressures, an estimation of the potential benefits of reaching GES is made where possible. Some pressures were assessed as equivalent to the GES. Due to this, the final list of components and pressures relevant for valuation was reduced to the following four components: (i) Fish, (ii) litter, (iii) subtidal benthic habitats and (iiii) birds. For each of these components, an estimation of the potential benefits of reaching GES is made, where possible.

> Ad i) If GES targets have been defined to ensure that key fish stocks reach MSY, a higher level, a sustainable provisioning level, will be reached. This implies a higher catch with associated benefits. Making assumptions underpinning the analysis, the benefits of reaching the MSY for 5 species is estimated to be £175m a year. Reaching GES can also have a positive effect on the recreational services related to fish stock (e.g. sea angling and diving).
>
> Ad ii) it is likely that in the BAU scenario, accumulation of litter in the sea will increase. Litter on beaches can negatively affect people's experiences through reduced recreational opportunities, loss of aesthetic value and loss of non-use values. Although these effects are likely to occur, when trying to express these impacts in monetary terms, the size of these benefits appear to be quite limited (van der Veeren and Keijser, 2013). Furthermore, it is likely that commercial fisheries will also be affected, due to damage caused by marine litter. Based on the answers on a questionnaire filled in by fishermen representing 18 vessels, the impact of litter on the fishing industry is estimated to be between £30.5m and £33.9m per year (about 5% of the total revenues generated by the UK fleet in 2009). If all litter will be removed, this is £344m in 10 years. Other sectors that will be affected by litter are aquaculture (about £1.2m in 10 years) and harbours and marinas (up to £19m in 10 years) both due to the costs of marine litter removal. As the GES target for litter aim to reduce litter, rather than remove litter completely, the benefits of achieving GES will be lower than the calculations carried out for complete litter removal.
>
> Ad iii) Given the existing evidence, it is difficult to determine the impact of degradation on the regulation services of subtidal benthic habitats, intertidal rocky habitats and intertidal sediment habitats.
>
> Ad iv) Without achieving the GES targets with respect to seabirds, some degradation will occur. This might have an impact on the cultural and aesthetic benefits that visitors achieve from sites with seabirds populations. Based on estimates of the current value of these cultural and aesthetic benefits, the costs of not reaching GES could be significant.

The UK ecosystem services approach analyses the welfare effect of four different components. Three of these components can be related to the state of the ecosystem, as expressed by GES indicators, D1 birds are one indicator of biological diversity, D3: commercially exploited fish and D10: litter. For these GES descriptors, the differences in welfare effects are investigated if possible. The provided ecosystem services, and impacts on human capital, taken into account in the UK assessment are summarised in Table 3.8.

Table 3.8 *Provided ecosystem services in UK marine waters affected by the degraded state of the ecosystem or affecting the state of the ecosystem. 'X' indicates which ecosystems services are directly taken into account, an 'i' indicates that there is an indirect link*

	D1: biological diversity: Birds	D3: commercially exploited fish	D6; seafloor integrity	D10; Litter
Provisional services				
Biotic: • Nutritional; fish catch		X		i
• Nutritional; aquaculture				X
HUMAN CAPITAL: • Physical use of marine ecosystems (e.g. commercial vessels): commercial fisheries will also be affected, due to damage caused by marine litter?				X
• Harbours: clean, safe and attractive port facilities				X
Regulation services				
• the regulation services of subtidal benthic habitats, intertidal rocky habitats and intertidal sediment habitats			?	
Cultural services				
Biotic • Recreation value	X	X		X
• Aesthetic benefits	X			X
Human capital • Physical use of marine ecosystems (e.g. sea anglers):				X

Source: HMGovernment (2012a; 2012b).

3.6 Conclusions

The ecosystem services (ESS) approach is increasingly proposed to be used in the calculation of the costs of degradation of the marine environment. It is an scientifically based bridge to link ecological studies to economic studies. Although the concept is appealing, the methodology and the empirical application is not mature enough yet, to be implemented in MSFD currently within the Netherlands or the EU. This conclusion is based on the following observations:

a. The main problem in the quantification of the value of ecosystem services provided in GES is the lack of data on GES descriptors/criteria and on the value of the different ecosystems for the beneficiaries, and the limited understanding of the functioning of the marine ecosystem.
b. An extra complicating factor is that monetary valuation of non-market goods is not widely accepted by policy makers in the Netherlands.
c. The provision of ecosystem services depends on a lot of biotic, physical and economic processes. The relevant relations are not known sufficiently to quantify the changes in ecosystem services.

To enable comparison of ESS studies to compute the costs of degradation coordination is required on some specific topics:

d. The quantity and value of ecosystem services depend on the input of human derived capital (HDC). There is no consensus on the methodology to value ESS with respect to HDC. Most studies neglect this human derived capital in their analyses. If HDC is ignored the value of ESS will be overestimated. In cooperation with other Member States, can be chosen to include costs of HDC in the analysis.
e. Ecosystem services can comprise biotic and abiotic services. Most studies focus solely on biotic services. The MSFD contains also abiotic descriptors. Hence, including abiotic services seems a logical choice.
f. Studies that use willingness to pay (WTP) in their ESS approach often do not use ecosystem services as attributes in the WTP-analysis. More guidance on WTP-studies is warranted to obtain useful and comparable stated preferences values for the costs of degradation

The additional value of the ecosystem services depends on the market conditions for these ecosystem services. The marginal value of additional ecosystem services is likely to decrease if supply increases. This reduced marginal value will affect the value of the extra ecosystem services supply. Other decisions on the delineation of the computation of ESS have to be made (e.g. to include abiotic stocks and flows) to acknowledge this methodology and its practical use.

Different views on ecosystem services exist, ranging from purely ecologic (focussing on ecosystems) to economic (focussing solely on human welfare). Hence, the application of the ecosystem services approach to determine the costs of degradation starts with a transparent delineation of the methodology applied.

In comparison to the cost benefit approach, the ecosystem services approach has a limited scope, since a subset of costs and benefits is included in the ESS, e.g. the costs of measures are not taken into account. The ambition incorporated in the ESS approach to determine the costs of degradation is to show the benefits of the Good Environmental Status (an improved provision of ecosystem services). These benefits are foregone in the business as usual scenario. By focusing on ecosystem services the assumption will be that it will be a positive factor. The comparison between GES and BAU could also be made based upon a CBA, providing policy relevant information on all costs and benefits of the GES considered. Based on this CBA policy makers could decide for a more strict GES or a less ambitious GES (if the benefit-cost balance is negative).

To establish a smooth link with economic studies with respect to the MSFD the following choices seem to be logical:

- Apply the combined biotic and abiotic definition of ecosystem services. Abiotic ecosystem services play a role in the delivery of biotic ecosystem services and have a value in their own right.
- An economic definition of ecosystem services prevents double counting of intermediate services
- Focus on supply and demand of ecosystem services to preclude overestimation of the value of ecosystem services, by incorporating excess supply for which demand is lacking
- Include the human costs to reap the ecosystem services' benefits, to include the net value of ecosystem services to determine the cost of degradation (instead of the gross benefits only)
- Select indicators that are directly related to ecosystem services in willingness to pay studies to attach a value on the gap analysis of these indicators.

The resulting ESS approach to determine the cost of degradation looks like a CBA. The difference lies in the costs of measures that are included in CBA, but not in the ecosystem services approach (which focusses solely on the benefits).

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Appendix 1 Consulted experts

For this report, the following experts were consulted:

- Buisman, Erik - Wageningen Econonomic Research
- Dekeling, René - Ministry of Infrastructure & the Environment & Ministry of Defense
- Haasnoot, Tim - ProSea
- KVNR (Koninklijke Vereniging van Nederlandse Reders)
- Mannaart, Mike - KIMO
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- Nieuwenhuize, Arno – Rijkswaterstaat Zee en Delta
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