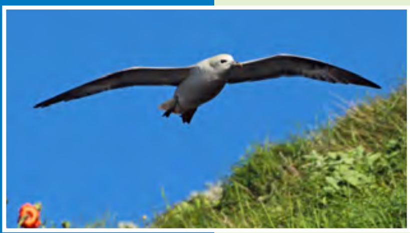
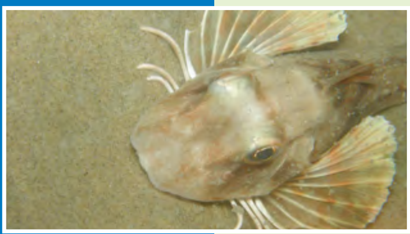
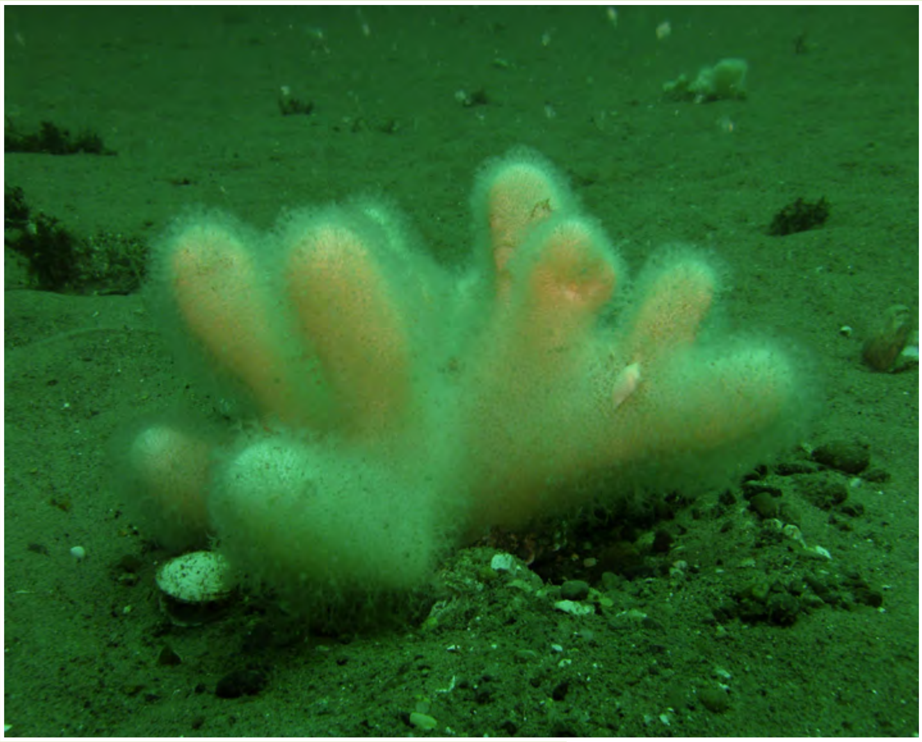
Evaluating biodiversity of the North Sea using Eco-points

Testing the applicability for MSFD assessments







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commissioned by: Directorate-General for Public Works and Water Management

23-12-2011
report nr 11-162

Status:	final
Report nr.:	11-162
Date of publication:	23-12-2011
Title:	Evaluating biodiversity of the North Sea using Eco-points
Subtitle:	Testing the applicability for MSFD assessments
Authors:	Drs. W.M. Liefveld Drs. K. Didderen Dr. W. Lengkeek Ing. M. Japink Drs. S. Bouma Ir. M.M. Visser
Number of pages incl. appendices:	101
Project nr:	11-374
Project manager:	Drs. W.M. Liefveld.
Name & address client:	Ministry of Infrastructure and the Environment P.o. box 20904 2500 EX Den Haag
Reference client:	Zaaknummer 31057943
Signed for publication:	Team manager Bureau Waardenburg bv Drs. S. Dirksen
Initials:	

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Summary

The objective of this study is to explore the use of Eco-points as a tool for evaluating biodiversity in cost-benefit analyses within the Marine Strategy Framework Directive (MSFD). Expressing biodiversity values in Eco-points provides a method for assessing the effects of management measures on North Sea biodiversity in a clear and repeatable way. The output of this study includes the design of an Eco-point framework, including biodiversity values of the North Sea that relate to MSFD descriptors. This framework is tested with the use of existing data and potential MSFD measures.

Building the framework

The basic principle of the Eco-point method is that the biodiversity within habitats is evaluated by three factors: 1) area (habitat surface area), 2) quality (i.e. number of species) and 3) a weighting factor that represents the importance of the specific habitat for maintaining overall biodiversity. Eco-points can be calculated by:

$$\text{Eco-point total} = \sum_{\text{all habitats}}(\text{Area} \times \text{Quality} \times \text{Weighting factor})_{\text{per habitat}}$$

To quantify the surface area of each habitat, we defined a habitat classification based on a simplified version of the EUNIS level 3 classification, to a level that covered the main important abiotic factors that result in large differences in species composition: shear stress, grain size and depth. This resulted in a concise list of 11 habitat types that fit the ‘Eco-point North Sea framework’ purpose.

To quantify the habitat quality, we selected metrics that comply with the MSFD indicators for GES descriptor 1 “biodiversity”. We selected communicable metrics for four species groups (benthos, fish, birds, mammals) with available data covering the entire Dutch Continental Shelf (DCS). Habitat quality was scaled from 0-1 for each metric. Since GES 1 comprises of maintaining current biodiversity levels, the maximum quality per metric per habitat was defined as the highest possible quality per habitat in the current situation.

To develop an appropriate weighting factor, we explored several options. A first option is relating the weighting factor to habitat rarity. The basic assumption of using habitat rarity as a weighting factor, is that each habitat has it’s own unique species community, and that one unit surface area of a rare habitat contributes more to total biodiversity than the same unit in a widespread habitat. We calculated the weighting factor as a direct function of the available surface area per habitat.

As an alternative method, we explored the possibility to include fidelity of species to specific habitats as a weighting factor. We calculated the weighting factor per habitat, by taking into account the inverse number of habitats where the species is found as a measure for its fidelity. In this way, habitats with species that occur in fewer habitats

and therefore have a high fidelity are considered as more valuable in contributing to the biodiversity of the North Sea. This approach is in line with the original approach of the weighting factor used in previous case studies. In this way habitats with higher numbers of species with high habitat fidelity are considered as more valuable in contributing to total biodiversity.

Implementation

In this study we first implemented data derived from Bos (*et al*. 2011) for the metrics used to assess habitat quality. The Eco-point framework was tested in two case studies with two selected MSFD measures: 1) "Introducing hard substrate items in bottom-protection zones" and 2) "litter reduction". We assessed the effects on biodiversity through effects on individual metrics. These estimations rely on a number of assumptions and were based on the best available expert knowledge. We calculated the number of Eco-points per measure. For measure 1, two scenarios were elaborated based on two different locations for the bottom-protection zone. The litter reduction measure was assumed to influence the entire Dutch Continental Shelf (DCS). The results indicate that a bottom protection zone on gravel habitat leads to higher benefits for biodiversity as expressed in Eco-points than a bottom protection zone of the same size in sandy habitat. Litter reduction did not result in Eco-points changes, since effects on the biodiversity metrics could not be assessed, let alone be quantified.

Scenarios

We also explored the potential of the incorporation of societal scenarios in the Eco-point methodology. These societal scenarios have been developed by the PBL Netherlands Environmental Assessment Agency ('Planbureau voor de Leefomgeving', hereafter PBL) and include a number of (key) principles that are translated into maps indicating the functions of different areas in the North Sea per scenario. These scenarios are: Vital nature, Recreational nature, Functional nature and Flexible nature.

Assessment of how measures planned for the MSFD descriptors are evaluated through different scenarios, requires a definition and quantification of indicators for the key principles of the scenarios. This requires additional research. Apart from the scenario Vital Nature, few key elements of the philosophies behind the scenarios can be linked in an unambiguous way to MSFD descriptors. Incorporation of societal scenarios in a weighting factor was not feasible at this stage. It may be possible however, to define and value spatial zones of interest per scenario in a cost-benefit analysis (CBA), based on the existing maps per scenario. Another option is to assess the effects MSFD measures directly per scenario as a societal scenario-analysis in a CBA.

Conclusion

The Eco-point framework has been prepared for application in CBA studies comparing different MSFD measures in terms of effects on biodiversity. The Eco-point method is useful, since the intrinsic value of nature can be incorporated in a single, clear and repeatable manner, and ranking of different options is enabled. In this way the Eco-point North Sea framework explicitly aims at quantifying effects of MSFD on biodiversity in a uniform way that is more useful than just comparing plusses and minuses. The methodology is flexible, transparent and communicable, and could therefore be helpful for decision-making or optimisation of location, size and type of restoration measures for the North Sea.

The current framework has potential for evaluating measures with established impacts on biodiversity in cost-benefit analysis. The outcome is useful in comparing scenarios. Future improvement of the method should include an in-depth study and adjustment of the included data, weighting factors and impact assessment of MSFD measures.

Samenvatting

Doel van deze studie is een verkenning van de geschiktheid van de Natuurpuntenmethode voor toepassing bij het wegen van biodiversiteitsaspecten in kosten-baten analyses voor de Europese KaderRichtlijn Mariene strategie (KRM). Het uitdrukken van biodiversiteitswaarden in Natuurpunten biedt een manier om de effecten van maatregelen op de biodiveristeit van de Noordzee te beoordelen op een transparante en herhaalbare manier. De resultaten van deze studie omvatten het Natuurpunten raamwerk, met biodiversiteitswaarden voor de Noordzee die passen bij de descriptoren van de KRM. Dit raamwerk is getest met bestaande data van biologische parameters van de Noordzee op mogelijke KRM-maatregelen.

Het Natuurpunten raamwerk

Het basisprincipe van de natuurpuntenmethode is dat de biodiversiteit van habitats uitgedrukt wordt in drie factoren: 1) de kwantiteit (areaal van de habitat), 2) de kwaliteit (b.v. aantal soorten binnen de habitat) en 3) een weegfactor die het belang van de betreffende habitat voor biodiversiteit weergeeft. Het aantal Natuurpunten wordt berekend volgens:

$$\text{Natuurpunten (totaal)} = \sum_{\text{alle habitats}}(\text{Areaal} \times \text{Kwaliteit} \times \text{Weegfactor})_{\text{per habitat}}$$

Om habitat areaal te berekenen, hebben we een indeling in habitattypen gemaakt, gebaseerd op een vereenvoudigde versie van de EUNIS niveau 3 – classificering. De toegepaste indeling is erop gericht in elk geval de belangrijkste abiotische factoren te onderscheiden die verschillen in soortensamenstelling bepalen: korrelgrootte, diepte en golfwerking (gerelateerd aan diepte). Dit resulteerde in een selectie van 11 habitattypen voor het Natuurpunten raamwerk voor de Noordzee.

Om de kwaliteit van habitattypen te kwantificeren hebben we parameters (verder metrieken genoemd) geselecteerd die overeenkomen met de KRM indicatoren voor de GES descriptor 1: ‘biodiversiteit’. We hebben de vier belangrijkste soortgroepen geselecteerd: benthos, vis, vogels en zoogdieren, en daarbij de metrieken geselecteerd die aansluiten bij de KRM en waar ook data van beschikbaar zijn voor de gehele Nederlandse deel van het Continentaal Plat (NCP). Habitatkwaliteit is uitgedrukt op een schaal van 0 tot 1 voor elke metriek. Omdat GES 1 zich richt op het behouden van het huidige niveau van biodiversiteit, is de maximale kwaliteit per metriek per habitat hier gedefinieerd als de hoogste waarde in de gebruikte datasets per metriek per habitat.

We hebben verschillende mogelijkheden verkend om een weegfactor te bepalen. De eerste mogelijkheid is om de weegfactor te relateren aan de zeldzaamheid van een habitat. Het onderliggende uitgangspunt hierbij is dat elk habitat zijn eigen unieke levensgemeenschap heeft en dat een bepaald oppervlak van een zeldzaam habitat meer bijdraagt aan de totale biodiversiteit dan datzelfde oppervlak in een veel

voorkomend habitat. De weegfactor is bepaald als functie van de aanwezige oppervlakte per habitat in het NCP.

Als alternatieve methode hebben we de mogelijkheid verkend om het aantal unieke soorten per habitat mee te nemen als weegfactor. Hierbij hebben we per soort bepaald in hoeveel habitats het voorkomt en dit weer per habitat verrekend op basis van het voorkomen van de soorten per habitat. Op deze manier worden habitats met veel soorten die in weinig andere habitats voorkomen (en dus unieker zijn) hoger gewaardeerd in hun bijdrage aan de biodiversiteit van de Noordzee. Deze benadering is meer in overeenstemming met de oorspronkelijke benadering van de weegfactor die is toegepast in eerdere studies.

Implementatie

Voor het kwantificeren van de metrieken voor habitatkwaliteit hebben we data verwerkt die afkomstig zijn van Bos (*et al*. 2011). Het opgestelde Natuurpunten raamwerk hebben we getest in twee case-studies met twee mogelijke KRM-maatregelen: 1) introduceren van hard substraat als bodembeschermingszone en 2) terugdringen van afval op zee. We hebben de effecten van deze maatregelen op biodiversiteit doorgerekend via de effecten van deze maatregelen op de afzonderlijke metrieken per soortgroep. Dit laatste hebben we gebaseerd op een aantal aannames en de best beschikbare kennis op dit moment. Per maatregel is het aantal Natuurpunten bepaald. Voor maatregel 1 zijn twee scenario's uitgewerkt, voor twee verschillende (fictieve) locaties waar het harde substraat wordt aangebacht.

In tegenstelling tot de eerste maatregel, heeft de maatregel met betrekking tot afvalreductie invloed op de gehele NCP. De resultaten duiden erop dat een bodembeschermingszone op grindbodem een grotere meerwaarde heeft voor biodiversiteit dan een vergelijkbare bodembeschermingszone in zandig habitat. Het terugdringen van afval op zee resulteerde niet in een toename in Natuurpunten. Omdat de effecten van deze maatregel op ecologische parameters (nog) niet bekend zijn, is het in dit stadium niet verantwoord hier een kwantitatieve maat aan te geven en hebben we ingeschat dat er geen effect op de metrieken is.

Kijkrichtingen voor natuur

We hebben onderzocht of de maatschappelijke kijkrichtingen voor natuur van het PlanBureau voor de Leefomgeving (PBL) in de Natuurpuntenmethodiek opgenomen kunnen worden. Dit met het idee dat het inbouwen van een relatie met maatschappelijke weging de natuurpuntenmethode nog geschikter zou kunnen maken voor toepassing in een MKBA.

De kijkrichtingen omvatten een aantal principes, die ook vertaald zijn in kaartbeelden, waarin de functies van de verschillende gebieden van de Noordzee per kijkrichting zijn vastgelegd. De kijkrichtingen zijn: Vitale natuur, Beleefbare natuur, Functionele natuur en Inpasbare natuur.

Om te beoordelen hoe KRM-maatregelen scoren bij deze kijkrichtingen, is het nodig de achterliggende principes per kijkrichting te kunnen kwantificeren. Hiervoor is nader onderzoek nodig. Van de vier kijkrichtingen geeft de kijkrichting Vitale natuur de meeste aanknopingspunten met de KRM descriptoren, voor de andere kijkrichtingen zijn weinig of geen relaties te leggen (of ze zijn niet eenduidig). Een vertaling naar een weegfactor voor de natuurpunten bleek in dit stadium dan ook niet mogelijk. Het is wel mogelijk om gebieden te wegen die een meerwaarde hebben bij een bepaalde kijkrichting. Een andere mogelijkheid is om de kijkrichtingen als maatschappelijke scenario's direct in te brengen in de MKBA.

Conclusie
De Natuurpuntenmethode is gereed gemaakt voor toepassing in MKBA-studies waarin KRM-maatregelen worden afgewogen in termen van biodiversiteit. Met de Natuurpuntenmethode kan de intrinsieke waarde van natuur op een transparante en herhaalbare manier worden meegenomen. De waarden, uitgedrukt in Natuurpunten, zijn echter niet als absolute getallen te hanteren, bijvoorbeeld als biodiveristeitswaarde. Het gaat om het *verschil* in natuurpunten waarmee scenario's vergeleken of geprioriteerd kunnen worden. Het op deze manier waarderen van effecten van de KRM-maatregelen geeft meer inzichten dan alleen het vergelijken van plussen en minnen. Het onderscheid in metrieken maakt het mogelijk om te zien waar de verschillen ontstaan en de kwantitatieve benadering maakt koppeling met waarden uit de MKBA (b.v. euro's) mogelijk. De methode is flexibel, transparant en makkelijk te begrijpen en kan op deze manier van nut zijn bij besluitvorming of optimalisatie van locatiekeuze, omvang of type maatregelen voor de Noordzee.

Het huidige raamwerk is geschikt voor het beoordelen van maatregelen waarvan de effecten op biodiversiteit bekend zijn. De resultaten kunnen gebruikt worden voor het vergelijken van scenario's. Voor verdere toepassing in een MKBA zou de methode nog verder verbeterd kunnen worden door nadere analyse en aanpassing van de gebruikte data en metrieken, de weegfactor en de inschatting van de effecten van maatregelen. De discussie (hoofdstuk 5) geeft hiervoor aanknopingspunten.

1 Introduction

This study explores the feasibility to apply the Eco-point method, developed by the PBL-The Netherlands), to quantify biodiversity of the Dutch North Sea and the impact of restoration measures for the European Marine Strategy Framework Directive (MSFD). If suitable, the method may be adapted and incorporated in future cost-benefit analyses of these measures.

1.1 Background

The European Marine Strategy Framework Directive (MSFD) has become effective on 15th of July 2008 (2008/56/EC; EC, 2008). The main objective is to achieve the “Good Environmental Status” (GES) of the European Union's (EU) marine waters and to design and implement programmes of measures aimed at achieving this goal by 2020, through an ecosystem approach to marine management. For the Netherlands this concerns the Dutch part of the North Sea. When regarding the programme of measures, Member States shall give due consideration to sustainable development and to the societal and economic impacts of these measures. In this context the MSFD explicitly demands for an economic analysis and a cost-benefit analysis (CBA). The economic and societal analysis for the Dutch part of the North Sea has recently been carried out and included in the Initial Assessment (Prins *et al.* 2011). In preparation for the actual cost-benefit analysis that will be carried out in 2012, a preliminary cost-benefit analysis is actually carried out by Reinhard *et al*. (2011). Their analysis includes an inventory of relevant measures, their costs and benefits and an estimation of socio-economic effects. Ecological effects, which cannot be monetized, are not included. Since the ecological impact is the main objective of the measures, it is critical to add ecological information to the cost-benefit analysis. Therefore, an objective translation of this ecological information, enabling comparison with socio-economic factors, is needed.

In the MSFD eleven qualitative descriptors of good environmental status have been identified (table 1.1). For each descriptor a number and variety of indicators are (in the process of being) defined by the European Commission, resulting in large numbers of indicators (over 40) (appendix 1). For incorporation in a CBA, these indicators are defined at a too general level. EU-guidelines do not give sufficient guidance for the practical implementation of the indicators in a CBA.

One way to value biodiversity in comparable and communicable dimensions, would be in terms of money. Biodiversity at sea is, however, difficult to express in an economic value; one obvious exception being fishing benefits. Therefore it is inadequate to apply a contingent valuation method[1] (CVM) in the MSFD context. The

[1] The contingent valuation method involves directly asking people, in a survey, how much they would be willing to pay for specific environmental services. In some cases, people are asked for the amount of compensation they would be willing to accept to give up specific environmental services.

‘willingness to pay’ to have more biodiversity at sea, or ‘willingness to accept’ a certain loss of biodiversity, cannot be quantified in a comprehensive way at this moment. The subject is simply too distant for most people that are not involved professionally in the sea-ecosystem. Fact is that most of the biodiversity at sea is hidden for the eye, as it is mostly under water or/and at a large distance (except for the coastal zone). Furthermore, the fact that CVM is based on what people say they would do, as opposed to what people are observed to do, is an important source of uncertainty. Application of CVM methods in a marine context is therefore controversial.

Another level of valuing changes in biodiversity would be in terms of plus and minus, as frequently applied in environmental impact assessments. This method can be useful in exploring scenario’s, but it does not match the quantitative level at which the costs are included in the CBA. Questions as how to weight one plus to another, or to a minus, cannot be solved in a comprehensive way.

Within the scope of the Water Framework Directive (WFD), a specific weighting system has been developed by means of Ecological Quality Ratio’s. These are based on an elaborate description of a natural reference situation (Van der Molen & Pot 2007). For terrestrial ecosystems another methodology has been developed that objectively expresses ecological benefits of measures in terms of Eco-points, a method that values biodiversity at the habitat-level (Grontmij 2011, Puijenbroek & Sijtsma 2010).

This study explores the applicability of this Eco-point method, developed by the PBL-The Netherlands, to quantify ecological benefits in the context of MSFD. This methodology facilitates a systematic comparison of different ecological effects by presenting them as an aggregated quantitative value. This clarifies the ecological differences between policies or scenarios of measures. When the outcome of this exploration is positive, the method may be applied in the CBA of the MSFD.

1.2 The European Marine Strategy Framework Directive (MSFD)

This study was initiated in the context of both the marine ecosystem of the North sea and the current policy development such as MSFD, WFD, OSPAR and Natura 2000, therein. The Eco-point methodology of the North Sea is particularly useful for incorporation in the cost-benefit analysis as a part of the MSFD process. This subsection describes the main aspects of MSFD that are relevant for this study. Since most other marine policies are interlinked with the MSFD, highlights of related policies and frameworks are summarised in appendix 4.

The main objective of the MSFD is to achieve the Good Environmental Status (GES) of the EU's marine waters in 2020. For each marine region or sub-region this GES has to be determined and an Initial Assessment (IA) of the current ecological state has to be carried out. Draft reports determining GES and the IA for the Dutch part of the North Sea have been produced by Deltares (Prins *et al*. 2011).

In order to provide guidance to these descriptors the European Commission prepared criteria and methodological standards for each descriptor, as well as related indicators, for assessing progress towards the GES (Commission Decision of 1st of September 2010). Member States need to consider these criteria and indicators in order to identify those that are to be used in their marine region or sub-region. Subsequently Member States need to identify monitoring parameters to assess these indicators. In May 2011, Deltares proposed environmental targets and associated indicators for MSFD descriptors (Boon *et al*., draft May 2011). Monitoring parameters have not yet been identified, although this process is in progress (Bouma & Liefveld 2011).

Table 1.1: MSFD Descriptors (see also appendix 1)

1	Biodiversity
2	Non-indigenous species
3	Fish populations
4	Food webs
5	Eutrophication
6	Sea bottom integrity
7	Hydrographical characteristics
8	Priority substances
9	Priority substances in fish
10	Marine litter
11	Under water noise

As the Eco-points method has been developed to quantify biodiversity-aspects, the current study focuses on GES 1: ‘Biological diversity is maintained. The quality and occurrence of habitats and the distribution and abundance of species are in line with prevailing physiographic, geographic and climate conditions.’ This is in fact a key-descriptor for the MSFD, that relates to all other descriptors (see also figure 2.2).

1.3 Eco-points

1.3.1 Natural Capital Index Framework

A method that can be considered as a forerunner of the Eco-points method is the Natural Capital Index Framework (NCI), that has been developed as a contribution to the implementation of the Convention on Biological Diversity (CBD). The framework has been designed in order to visualise and quantify biodiversity loss (or gain) for policymakers and the public alike (Ten Brink *et al*. 2002).

The framework incorporates the two main components of biodiversity:

- Factor 1 (x-axis): Ecosystem quantity. Loss of habitats, resulting from the conversion of natural areas to agricultural or urban use will lead to a decrease in 'ecosystem quantity';
- Factor 2 (y-axis): Ecosystem quality. The decline in ecosystem quality is shown by the decreasing abundance of many characteristic species due to factors such as climate change, pollution, habitat fragmentation and over-exploitation. Current Ecosystem quality is defined as the ratio between the current situation and baseline state (percentage of the baseline).

NCI is defined as the product of the size of the remaining area (quantity) and its quality: NCI = ecosystem quantity (%) x ecosystem quality (%).

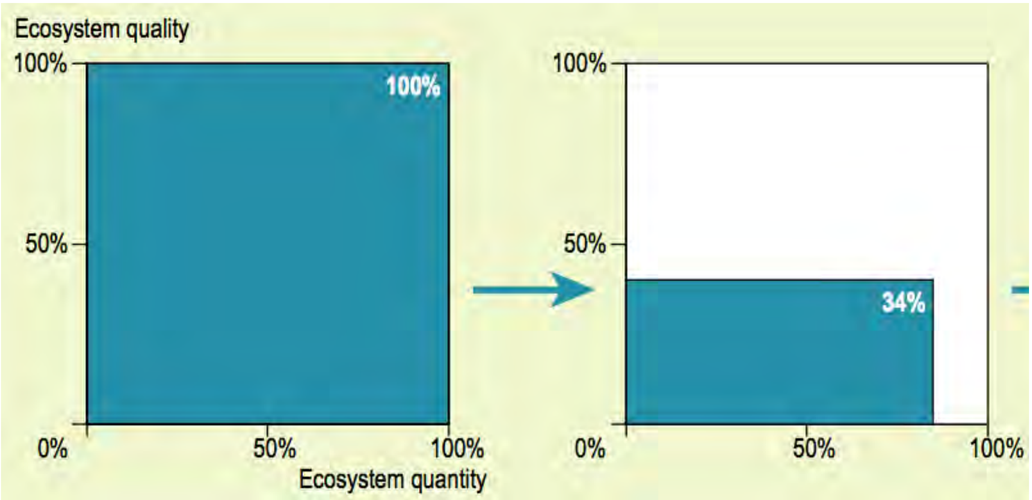

Figure 1.1 NCI principle. Biodiversity loss is measured (Ten Brink et al. 2002) by the product of ecosystem quantity (x-axis) decrease and ecosystem quality (y-axis) decrease. Left: situation with NCI = 100%. Right: hypothetical situation where 42,5% remaining quality and 80% remaining area results in a NCI of 34%.

The nature quality has been established using data on the abundance of certain species of plants, birds, mammals, reptiles, fishes, aquatic macroinvertebrates, butterflies and molluscs. Characteristic species have been selected for each ecosystem type (Ten Brink *et al.* 2002). Both factors work independently: a change in ecosystem quantity does not automatically lead to a change in ecosystem quality.

1.3.2 Eco-points

The Eco-point valuation method is an extension of the Natural Capital Index, as it also takes into account a weighting factor, which is based on the fraction of the total biodiversity that is represented by the specific ecosystem or habitat (Sijtsma et al. 2009). In formula (Equation 1):

Eco-point total = $\sum_{\text{all habitats}}(\text{Area} \times \text{Quality} \times \text{Weighting factor})_{\text{per habitat}}$

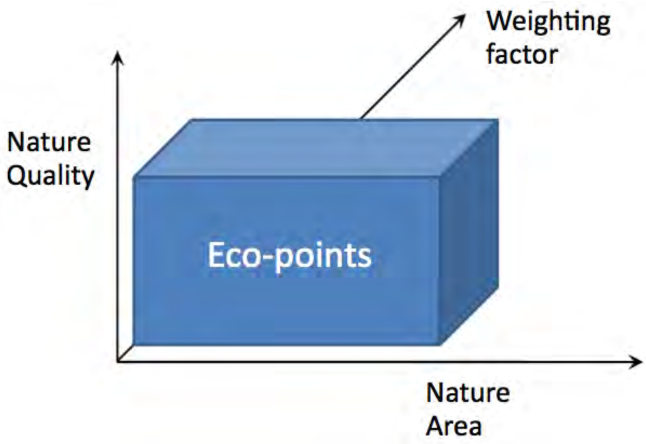

Figure 1.2: Schematic presentation of the Eco-points method

As not all habitats are regarded to be of equal importance, habitats are weighted. The weighting factor reflects the importance, threat or rarity of the habitat type at the national level. For terrestrial ecosystems the weighting factor for each habitat is calculated by the average normalised value for habitat fidelity of the species that occur in the specific habitat (Sijtsma *et al*. 2009). Habitat fidelity is not a 0/1 state but is calculated as a specific fidelity of a species for one or certain habitats, using the inverse number of habitats the species occurs in as its value.number of species. In this way species that occur in few habitats are characterised by a higher habitat fidelity. Per habitat the total habitat fidelity is calculated as the sum for all species.that occur in the specific habitat.

The Eco-point framework is a method that can be helpful to policy decision makers *i.e.* in:

- Comparing a future status with a current status;
- Comparing the effects of different measures;
- Including nature in policy decision making;
- Including nature in (societal) cost-benefit analysis.

So far the method has been applied in studies comprising both terrestrial and aquatic ecosystems (Sijtsma et al. 2009, Puijenbroek & Sijtsma 2010, Wessels et al. 2011). In the Afsluitdijk case, for example, effects on the freshwater Lake IJsselmeer, marshlands and meadows and the intertidal area of the Wadden Sea were included in the calculations (Wessels et al. 2011, Grontmij 2011). The calculated Eco-points enabled comparison with costs (in euro's). The basic principle of the Eco-points method is to take he ecological effects into account to the extend that they have an impact. In the application to the Afsluitdijk, the extent to which effects were included in the calculations turned out to be a factor that influenced the results strongly (Wessels et al. 2011).

1.4 Objective

The objective of this study is to examine the applicability of Eco-points in cost-benefit analysis for the implementation of the MSFD. The output of this study includes the design of a framework suitable for North Sea ecological values for those descriptors that can be meaningfully quantified. In order to determine both the scope and sensitivity of the method the framework is tested on existing data. We examine the applicability to current MSFD objectives and measures, and to future projects. We analyse the testing results, and give recommendations for further development of the method. Development and exploration of the method is the primary objective, the exact outcome in terms of Eco-points for actual MSFD measures is secondary.

2 Building the conceptual framework

2.1 Method

In developing of the Eco-points method for the North Sea we identified seven major components (figure 2.1):

1) Selecting descriptors (§2.2);
2) Definition and selection of habitat quality indicators (§2.3);
3) Identification of suitable indicators and metrics (§2.3);
4) Definition of habitat quantity (habitat types §2.4)
5) Development and inclusion of weighting factor (§2.5);
6) Development of the Eco-point framework (§2.6);
7) Calibration and fine tuning of the framework (§2.7);
8) Selection and definition of measures (§3.3);
9) Testing the framework for effect of selected measures (chapter 3).

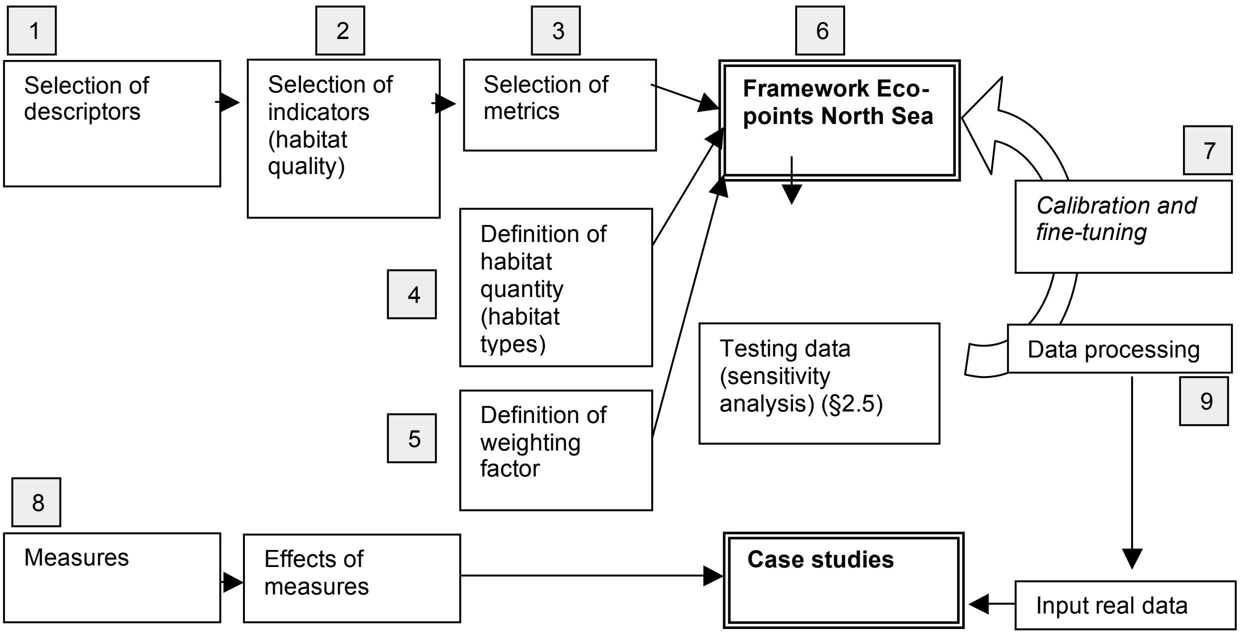

Figure 2.1 Outline of the steps in developing an Eco-point method for the North Sea.

2.2 Selection of descriptors

The MSFD mentions eleven descriptors for determining a good environmental status (table 1.1). Borja *et al.* (2010) present a conceptual model that describes the hierarchy in the eleven descriptors, and the connections between descriptors and pressures. Their model emphasizes that there are a number of descriptors that are directly related to specific pressures, while other descriptors (in particular Biological diversity and Food webs) have a more indirect relation to many different pressures (Figure 2.2).

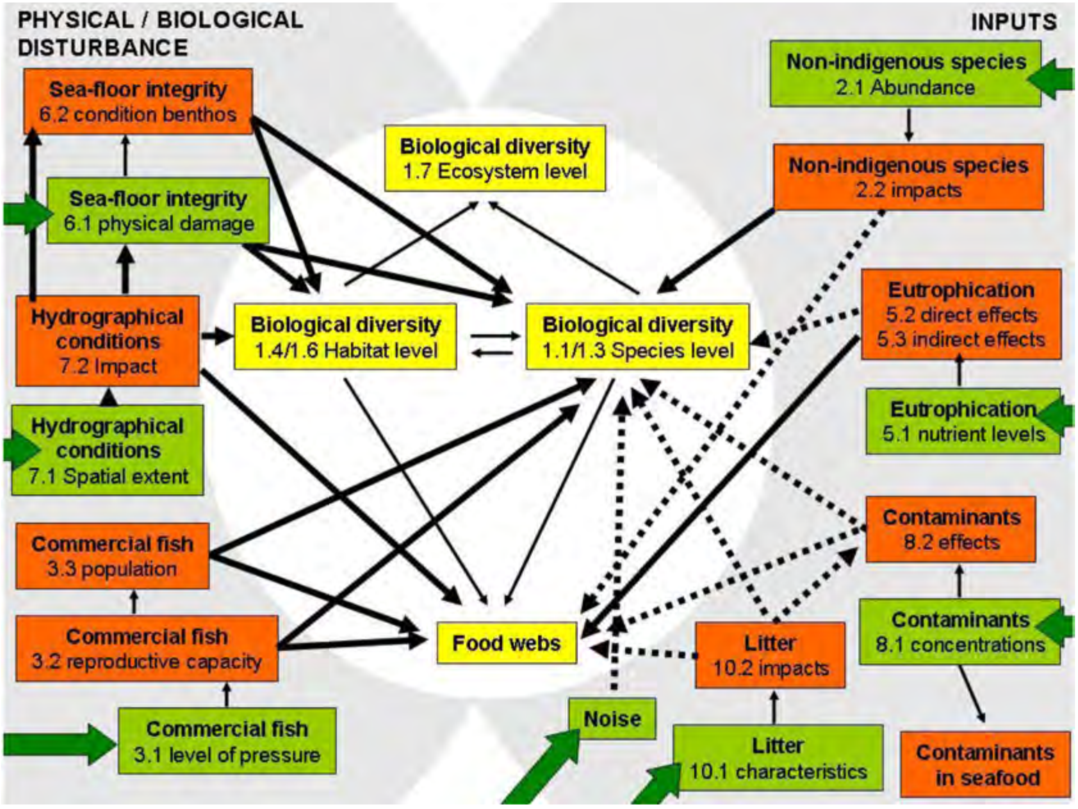

Figure 2.2 A conceptual model showing how the criteria (and related indicators) for the 11 qualitative descriptors are linked. Solid lines indicate strong links, dotted lines indicate weaker links. Dark green arrows indicate human pressures. Green boxes refer to pressure-related criteria, yellow boxes refer to state-related criteria and orange boxes refer to impact-related criteria (Boon et al. 2011).

As an elaboration on the conceptual model of Borja *et al.* (2010), Boon *et al*. (2011) proposed a model where a number of GES descriptors (2, 5, 8, 9, 10, 11) and their indicators are related to "input" pressures, *i.e.* pressures caused by the input of substances, organisms, litter or energy. These descriptors are shown on the right-hand side of figure 2.2. Other descriptors (3, 6, 7) are mainly related to physical or biological disturbance, by extraction of species or disturbance of habitats (shown on the left-hand side of figure 3.1). The two descriptors Biological diversity and Food webs are, as suggested by Borja *et al*. (2010), more indirectly influenced by pressures and could be considered to integrate the effects of human pressures on the other descriptors (figure 2.2). This makes them particularly valuable as parameters that relate to biodiversity. Descriptors that relate to 'Food-webs' without exception also relate to biodiversity (figure 2.2). Therefore in this study we choose to focus on GES 1: Biodiversity. In §5.2.3 we discuss the options to implement other descriptors into the Eco-point methodology.

2.3 Definition and selection of habitats

In order to estimate habitat quantity, habitats as an entity must be defined. Therefore, an integral aspect of the ‘Eco-point North Sea framework’ is the selection and definition of habitat types. In this study, the area of focus is the entire Dutch Continental Shelf (DCS).

2.3.1 Habitat classifications

Several habitat classifications exist for the DCS, i.e.: the classification of the Habitat Directive, with only two habitat types for the DCS, the EUNIS level 3 classification (Davies *et al*. 2004), with over 31 habitat types for the DCS and an aggregation of the EUNIS classification (Lindeboom *et al*. 2008), resulting in five habitat types for the DCS. We considered these habitat classifications to propose a classification that fits the purpose of this study.

2.3.2 Eco-point North Sea habitats

In order to apply the ‘Eco-point North Sea Framework’ successfully, we propose a simplification of the EUNIS level 3 classification by Bos *et al.* (2011) to a level which covers the main important abiotic factors that result in large differences in species composition according to Lindeboom *et al*. (2008) (shear stress, grain size, silt content and depth). We attempted to make a classification based mostly on arguments from literature; however, some degree of expert judgement has been used to end up with a concise list of 11 habitat types that fits othe ‘Eco-point North Sea framework’ purpose (Table 2.1).

Table 2.1 Proposed habitat classification of the Dutch continental shelf for the development and application of the Eco-point North Sea Framework. This represents a simplification of the classification proposed by Bos et al. 2011 (original habitat N°) and addition of habitat 11.

	Proposed habitat types	**Original habitat N°**
1	Estuary	1
2	Surf zone (sand, 0-10 m depth)	14,15,16,17
3	Shallow coastal sea (sand, 10-20 m depth)	24,25,26,27
4	Silty sand 20-40m (silt content >=15%)	31,32,33,41,42,43
5	(Medium) fine sand (<210um), 20-40 m depth	34,35,44,45
6	(Medium) coarse sand (>210 um), 20-40 m depth	36,37,46,47
7	Silty sand >40m (silt content >=15%)	51,52
8	(Medium) fine sand (<210um), >40 m depth	54,55
9	(Medium) coarse sand (>210 um), >40 m depth	56,57
10	Gravel (gravel content >=50%)	58
11	Man-made hard substrates (e.g windfarms, platforms, (ship)wrecks)	

The motivation for this classification is as follows:

- In shallow coastal seas shear stress and salinity are dominant factors. Estuaries should therefore be a separate habitat type because salinity is an important factor for benthos and fish species composition. Furthermore, their connectivity to river systems has an important ecological function.
- The surf zone should be a separate habitat factor because it is the zone with by far most shear stress, which is an important factor for benthic species composition.
- The shallow coastal sea (10-20m depth) should be a separate habitat type because shear stress is still relevant here, but also because resources for birds feeding on benthic life are still at an accessible depth.
- Further out at sea, where shear stress and salinity are less dominant factors, silt content and grain size are important so we define three habitats in the depth stratum 20-40m: 1) Silty sand 20-40m (silt content >=15%), 2) fine and medium fine sand (<210um), 20-40 m depth and 3) coarse and medium coarse sand (>210 um), 20-40 m depth.
- Deeper than 40m shear stress is even less important, (as a consequence) silt content can be higher and light conditions can differ markedly from shallower seas. We therefore define three more grains size based habitat types water deeper than 40 m: 1) Silty sand >40m (silt content >=15%), 2) fine and medium fine sand (<210um), >40m depth and 3) coarse and medium coarse sand (>210 um), >40m depth.
- We define a separate habitat type for areas with high gravel content (> 1 mm, >=50%), as a high gravel content allows for the development of hard substrate (reef) communities and differ markedly in their species composition from soft substrates.
- Ultimately we add one important habitat type (especially when considering biodiversity) that is being omitted in most studies: Man-made hard substrates such as shipwrecks and offshore installations. These hard substrates harbour a substantial part of the DCS biodiversity and mostly species that are not found on other habitat types (Lengkeek *et al*. 2011). This habitat type should therefore be included in future habitat classifications. As no complete data were available at this moment, the habitat type was not included in further analyses (chapter 3).

Data - availability

By aggregating the EUNIS level 3 habitats, a new habitat map was created (§6.2). It is beyond the scope of this study to add any habitat type for which we do not have accurate geographical data. We therefore omit ‘man made hard substrates’ for the time being but recommend that this habitat type is included in future use of this method.

2.4 Selection of habitat quality indicators and metrics

2.4.1 Biodiversity components in the North Sea

Biodiversity components of the North Sea that could be used to assess the quality component of the Eco-point method consist of 3 levels (species, habitats and ecosystems) and several species groups therein (bacteria, phytoplankton, zooplankton, algae, benthos, fish, birds and marine mammals, figure 2.3). The final set of indicators should preferably cover this diversity of ecosystem components. Natural changes in single species relative abundance within communities are beyond the control of normal management measures. It is therefore preferable to consider indicators at a broader level of functional groups of species and functional habitats (OSPAR 2011).

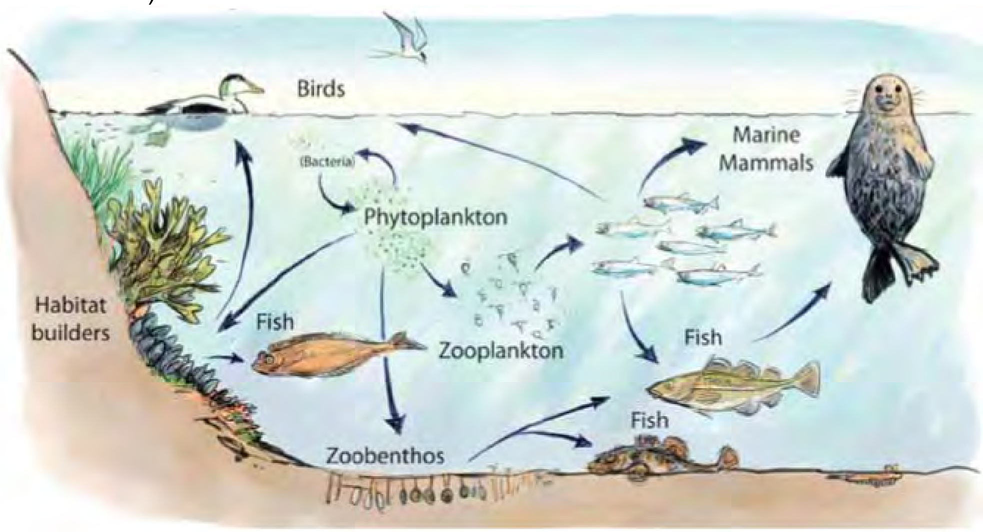

Figure 2.3 A schematic presentation of the simplified food-web structure in the North Sea (as adopted from the Baltic Sea, Helcom 2010).

2.4.2 Single vs multimetric

The search for habitat quality indicators that express biodiversity, starts off with the apprehension that for the Eco-point framework a multimetric approach is favoured over univariate approaches. Overall, the use of a single univariate indicator is a too drastic reduction of the environmental complexity to provide a clear conclusion of the system's quality status, especially when considering biodiversity of an entire ecosystem. Guidance from experts on the utility of indicators therefore tends to favour a combination of several indicators in order to evaluate the complexity of biodiversity and of the ecosystem, and to reduce the level of uncertainty of the results (van Hoey *et al.*, 2010, Dauvin, 2007).

The minimum number of ecological variables to be taken into account for multimetric indicators should be based on studies testing the compatibility of indicators so that they do not provide conflicting information for managers or provide the same information in different ways and thus obscure overall patterns, as such avoiding redundancy (e.g. Borja *et al*., 2007). A multimetric approach has been adopted since several indicators with complementary properties, combined in one or another way, may be needed to provide strong and effective support for management decision-making (van Hoey *et al.* 2010).

2.4.3 Available indicators, metrics and data for biodiversity

The search for and use of indicators for the MSFD and especially biodiversity within the MSFD has been subject to many studies, workshops and publications.
Selection of indicators was based on indicators mentioned in:

- EU indicators (European Commission decision, 1 september 2010);
- OSPAR Advice Manual (June 2011);
- Marine Strategy Framework Directive Targets and Indicators (Boon et al. 2011);
- Task Group 1 Report: Biological Diversity (Cochrane et al. 2010);
- OSPAR EcoQO (Heslenfeld & Enserink 2008);
- Ecoprofiles of indicator species (Meesters et al. 2008);
- Overview of indicators for Good Environmental Status (Langenberg & Troost 2008);
- Biodiversity hotspots of the Dutch Continental Shelf (Bos et al. 2011)

Available data are mentioned in:

- Smit *et al*. (2010) give an extensive summary of available marine monitoring series in the Netherlands.
- Biodiversity hotspots of the Dutch Continental Shelf (Bos *et al*. 2011) includes an overview of available data on benthos, fish, birds and marine mammals in the Dutch Continental Shelf.

2.4.4 Selection of metrics and data

For the development of the Eco-points method for the North Sea, we used metrics and data of the maps as described in "Biodiversity hotspots on the Dutch Continental Shelf" (Bos *et al*. 2011) as a basis. These were the only readily available spatial data on the biodiversity of the Dutch North Sea at the time. Origin, processing steps and restrictions of these data are described in this report and summarised in (appendix 2). Raw data (*i.e.* underlying single species data, most unclassified data) and unpublished data (*e.g.* Triple D dredge) were not available. Furthermore, bird data were aggregated to a single map/parameter ("bird value"). Marine mammal maps were all derived from density maps that were largely based on expert judgment. The purpose of the study by Bos et al. (2011) was to identify areas in the Dutch North Sea that contain a relative high level of biodiversity. Rescaling of intermediate values took place on the scale of the whole area of the North Sea, not just within habitats. A maximum level (or reference level), as used in the Natural Capital Index, was not set.

In accordance with Bos *et al*. (2011) we selected the four mean species groups as a basis for metrics selection: benthos, fish, birds and marine mammals. For each species group, Bos *et al.* 2011 analysed the current status of the DCS for specific metrics for biodiversity (appendix 5).

In addition to the general criteria for the selection of suitable indicators (appendix 3), we imposed some extra criteria for the purpose of this study:

1. Data readily available in current project;
2. Data based on real data;
3. Data easy to communicate.

This led to a selection of 11 metrics that could be used as a start off set to test the framework (table 2.2).

Exclusion of the metrics evenness, resilience and importance DCS were based on the fact that they are difficult to interpret and it is hard to establish effects of measures on these metrics (Communication). Since Bird value is the only available indicator of this group, it was selected for this study, despite its complex interpretability.

Table 2.2 Potential biodiversity metrics that spatially cover DCS. Long list derived from (Bos et al. 2011). Selection criteria: MSFD indicator: the related indicators as proposed in EU Commission decision (see appendix 1). Availability: 0 = data not available, 1 = basic data available, 1^{*} = rescaled data available, 1^{**}= rescaled data, based on expert judgement available, 1^{***} aggregated and weighted value available. Communication: - = difficult to interpret, Eco-point metric: x = used as metric in this study.

Species group	Metric	MSFD criteria	Availability	Communication	Eco-point metric
Benthos	distribition	1.1	0		
	trend	1.1/1.6.1	0		
	rarity	1.3.1	1^{*}		x
	resilience	1.3.1	1^{*}	-	
	large ind. within species	1.3.1	0		
	importance dsc for species	1.3.1	0		
	species richness	1.6.1/1.7.1	1^{*}		x
	species evenness	1.6.1/1.7.1	1^{*}	-	
	density	1.2.1	1^{*}		x
	biomass	1.2.1	1^{*}		x
	large species	1.3.1/1.6.2	1^{*}		x
Fish	distribition	1.1	0		
	trend	1.1/1.6.1	1		x
	rarity	1.3.1	1		x
	resilience	1.3.1	0	-	
	importance dsc for species	1.3.1/1.6.2	0		
	large ind. within species	1.3.1/1.6.2	1		x
	species richness	1.6.1/1.7.1	1		x
	species evenness	1.6.1/1.7.1	1	-	
	density	1.2.1	0		
	biomass	1.2.1	0		
	large species	1.3.1/1.6.2	1		x
Marine mammals	distribition	1.1	1^{**}		
	trend	1.1/1.6.1	1^{**}		
	rarity	1.3.1	1^{**}		
	resilience	1.3.1	1^{**}	-	
	importance dsc for species	1.3.1/1.6.2	1^{**}		
	species richness	1.6.1/1.7.1	1^{**}		
	density	1.2.1	1^{**}		x
Birds	distribition	1.1	0		
	trend	1.1/1.6.1	0		
	rarity	1.3.1	0		
	marine species	1.3.1	0		
	breeding in nl	1.3.1	0		
	importance dsc for species	1.3.1	0		
	resilience	1.3.1	0	-	
	species richness	1.6.1/1.7.1	0		
	species evenness	1.6.1/1.7.1	0	-	
	density	1.2.1	0		
	Bird value	1.7.1	1^{***}	-	x

2.5 Development and inclusion of weighting factor

For the third Eco-point factor; the weighting factor for each habitat, we explored different options. The first option we explored is to relate the weighting factor to habitat rarity. In this approach habitat types with a small surface area are more valuable to biodiversity than habitat types that are abundant. A second option we explored is a weighting of the habitat fidelity of species per habitat type. This approach corresponds more closely to earlier terrestrial Eco-point studies, but runs into several practical difficulties.

2.5.1 Habitat rarity as weighting factor

The basic assumption of using habitat rarity as a weighting factor, is that each habitat has it's own unique species community, and that 1 unit surface area of a rare habitat contributes more to total biodiversity than the same unit in a widespread habitat. A common way to calculate habitat rarity is as a function of habitat area, where smaller habitats are more rare.

We calculated the weighting factor as a direct function of the available surface area per habitat (Table 2.3) (Equation 2):

$$\textit{Weighting factor habitat a} = \frac{\textit{total surface area DSC}}{\textit{surface area habitat a}}$$

This was normalised for all habitats (Equation 3):

$$\textit{Normalised weighting factor habitat a} = \frac{\textit{Weighting factor habitat a}}{\textit{average weighting factor}}$$

Advantage of this approach is that it is objective and reproducible. Disadvantage is that the weighting factor changes as the surface area of habitat types changes. This is especially complicating in studies that include measures of habitat-creation. Furthermore in this study we consider habitat rarity related to available surface area within the study area, in this case the Dutch North Sea (DCS). As a consequence small surface areas of rare habitat types are compensated by a proportional higher weighting factor. As a result the factor habitat quality remains the dominant factor in Eco-point calculations. This is only true for calculations that concern the whole DCS area and not for calculations in restricted areas within the DCS (i.e. § 3.4 vs 3.5).

An alternative approach would be to consider rarity of habitats on a European level (the MSFD-level). An advantage of this alternative approach is that it is less sensitive to changes of habitat surface area. Also the scale is more in line with the MSFD concept. Disadvantage is that comparable spatial information in terms of habitat mapping is needed at a European level. Such a habitat map is only available for several countries at present, and combining them would demand further unification of the habitat definitions per country.

Table 2.3 Surface area, habitat rarity, habitat fidelity and normalised weighting factors 1 (habitat rarity) and 2 (habitat fidelity) per habitat type.

	habitat type	area (km^2)	habitat rarity	normalised weighting factor 1	habitat fidelity	normalised weighting factor 2
1	Estuary	4028	15	0,24	*n.a.*	*n.a.*
2	Surf zone (sand, 0-10 m)	1665	37	0,58	2,46	0,84
3	Shallow coastal sea (sand, 10-20 m)	3218	19	0,30	2,44	0,84
4	Silty sand (20-40m)	4573	14	0,21	2,06	0,7
5	Fine and medium fine sand (20-40 m)	12949	5	0,07	2,63	0,9
6	Coarse and medium coarse sand (20-40 m)	23175	3	0,04	2,90	0,99
7	Silty sand (>40m)	3175	20	0,30	2,38	0,81
8	Fine and medium fine sand (>40 m)	8483	7	0,11	2,50	0,85
9	Coarse and medium coarse sand (>40m)	834	75	1,15	*n.a.*	*n.a.*
10	Gravel	137	454	7,00	6,03	2,06

Mapping habitat rarity

For processing of the habitat rarity map, the normalised weighting factors (table 2.3) were used and linked to appropriate aggregated habitat taps. Figure 2.4 shows the rarity map and the final gridded rarity map. Since transitional and coastal waters are not part of the MSFD they were excluded from the map.

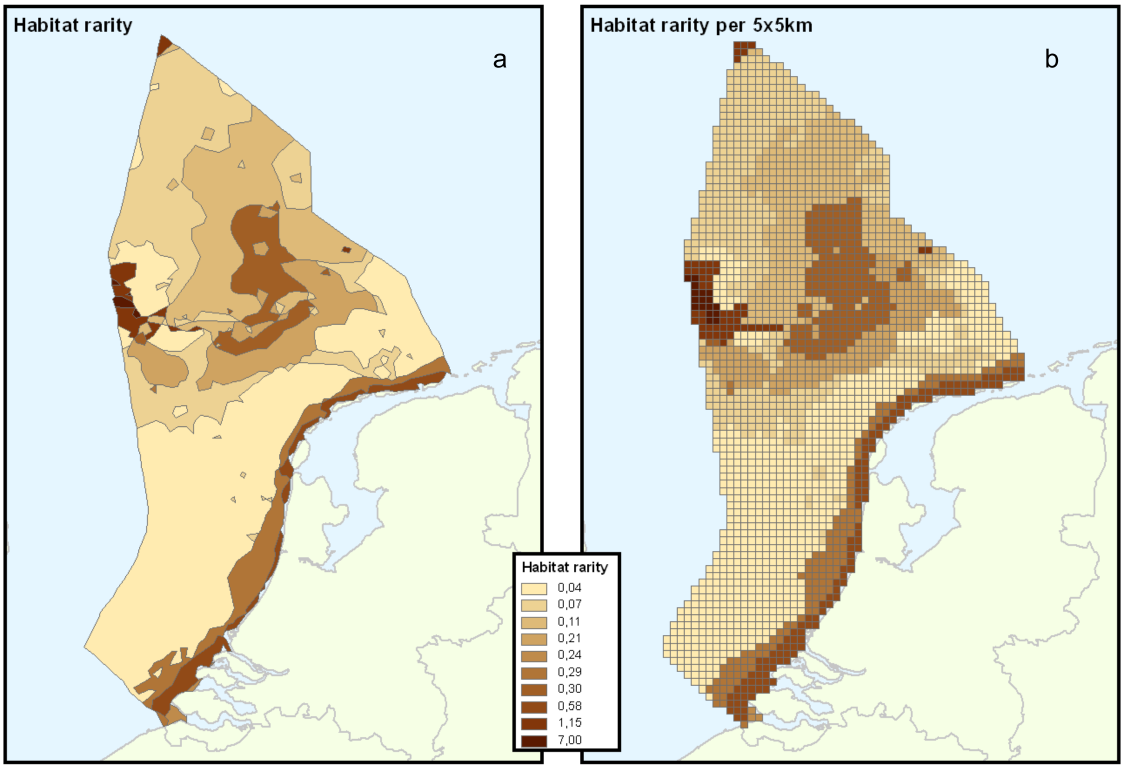

Figure 2.4 a. Rarity of habitats on the DCS based on equation 2 and 3. b Gridded map of rarity values. (data source: IMARES)

2.5.2 Habitat fidelity of species as weighting factor

Another way to express the contribution of habitats to biodiversity, is based on the habitat fidelity of the species in a habitat. This approach is more native to the Eco-point method as designed by PBL (Sijtsma et al., 2009) and freshwater and saltwater nature near the Afsluitdijk (Wessels *et al.*, 2011). The fidelity of species (the extent to which species are limited to a restricted number of habitats) determines the weighting factor for each habitat. Thus the weighting factor of a habitat relates to the amount of biodiversity that may be lost when the habitat is lost altogether. A low weighting factor implies that the average habitat fidelity of the species is low and species occur in several other habitats. However a high weighting factor implies that a habitat contains a large number of species that are more or less specific for that habitat and hence show a high habitat fidelity.

Calculation method
Ideally, all species groups should be incorporated into the calculation of the weighting factors. However, because of limited data availability, only macrobenthos is included at this point. Nevertheless, of all species groups, macrobenthos is the most suitable indicator for this purpose (see also §5.1.1). The data consists of the North Sea sediment samples that were collected in the Biomon-programme for macrobenthos over the period 1991-2005 (RWS, 2007). This includes 100 sampling points spread all over the Dutch Continental Shelf (DCS), which were sampled once a year with a Van Veen Grabber. The Biomon-dataset contains only one sampling station in the Natura 2000 region of the Cleaverbank, but this sampling station is not situated in the habitat that the Cleaverbank is specifically assigned for as Natura 2000 area, i.e. reefs habitat on stable coarse sands and gravel. Therefore, added to the Biomon-data was a dataset of macrobenthos of the Cleaverbank, where in 2002 100 samples were taken from the area containing gravel and coarse sands using a Hamon grabber (Van Moorsel, 2003). The lists of taxa were combined and checked against the World Register of Marine Species (WORMS, 2011). Only species (not genera or families) were included in the calculations (figure 2.5).

All sampling points were assigned to a habitat, using the simplified habitat EUNIS classification (see table 2.1) and the polygonal map of habitats (Figure 2.8a). Man-made substrate (habitat 11) was not included. Habitat 1 (estuaries) and habitat 9 (coarse sand below 40m) were excluded because not one of the sampling stations is situated within its boundaries. Due to lack of detailed species data on the individual sampling stations of the Cleaverbank, all Cleaverbank 2002 stations were assigned to habitat 10 (gravel). Thus 8 habitats remain.

Species fidelity for habitats was calculated by scoring the number of habitats a species was found in, dividing it by the total number of habitats, and subtracting this number from 1 (equation 4). Thus a species occurring in only one habitat was assigned a value of 0.875 (=1 – (1/8)). Likewise, a species that was found in all habitats was assigned the value 0.

Equation 4:

$$\textit{Species habitat fidelity} = 1 - \left(\frac{\textit{number of habitats where species is present}}{\textit{total number of habitats}}\right)$$

Equation 5:

$$\textit{Habitat fidelity} = \sum \frac{(\textit{species habitat fidelity})_{\textit{all species in habitat}}}{\textit{number of species in habitat}}$$

The habitat weighting factor based on habitat fidelity was calculated by averaging all species specific habitat fidelity values (equation 5) for the species in that specific habitat. The normalised weighting factor of a habitat was calculated by dividing the weighting factor by the average weighting factor of all habitats (equation 6). Thus a normalised habitat weighting factor larger than 1 indicates that a large fraction of the species found in that habitat occur in that habitat only, or in only a few habitats (table 2.4). A normalised habitat weighting factor of 0 indicates that this habitat contains only species that were found in all habitats present.

Equation 6:

$$\textit{Normalised habitat fidelity} = \frac{\textit{habitat fidelity}}{\textit{average habitat fidelity}}$$

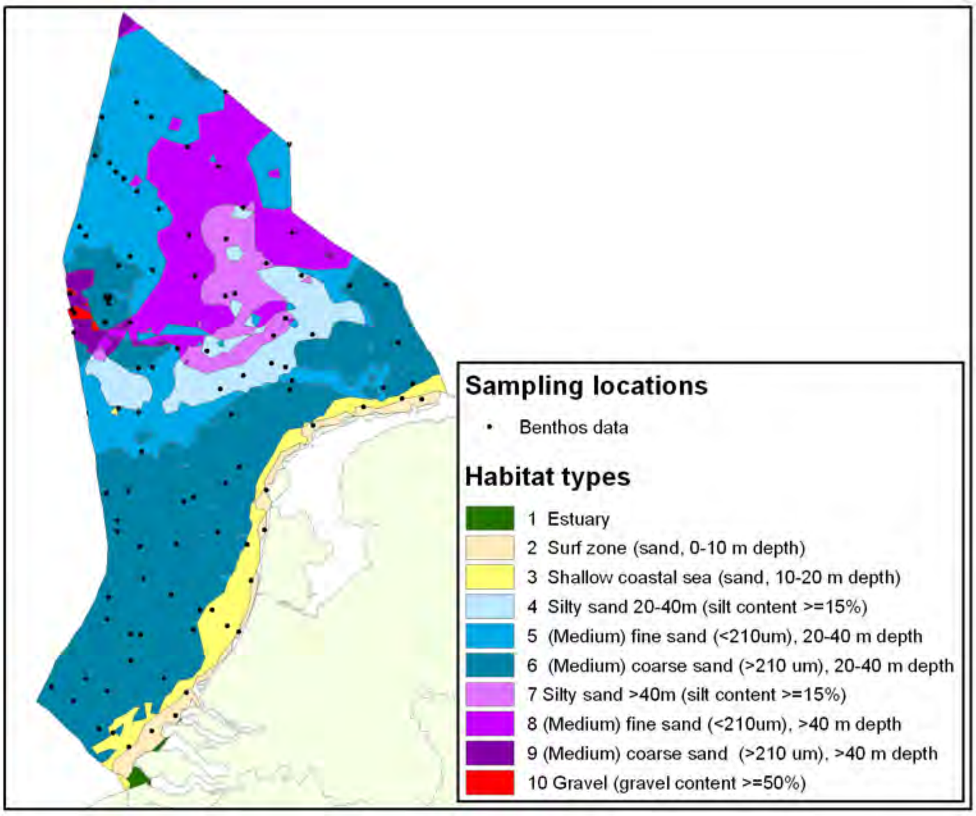

Figure 2.5 Sampling locations of benthos data used for calculation of weighting factor based on habitat fidelity. (data source: IMARES and van Moorsel 2003).

Results
The standardized Habitat weighting factors range from 0.7 to 2.1, giving a factor of 3 difference between highest and lowest factor (table 2.4). Gravel habitat received the highest score, whereas silty sand between 20 and 40 m depth received the lowest score. According to these results, the habitat silty sand between 20 and 40 m depth contributes the least to the macrobenthos biodiversity of the North Sea.

The total number of species was highest for the gravel habitat (on the Cleaverbank, 379 species) and lowest for silty sand between 20-40m depth (172 species). The number of unique species shows a more skewed pattern with 188 unique species for the habitat gravel (highest) and only 3 unique species for the habitat silty sand between 20-40m depth (lowest).

We also explored the options to include societal scenarios as a weighting factor. The outcome of this exercise is described in chapter 4.

2.6 Development of the Eco-point framework

2.6.1 The framework

The basis of the conceptual framework for Eco-points on the North Sea is the spatial information represented by the habitat map (figure 2.6). This represents factor 1: the quantity of ecological values. We interpret this as the surface area per habitat type. Secondly, the habitat quality is represented by the selected metrics for the indicators benthos, fish, marine mammals and birds. The input for these metrics depends on spatial data for the different species groups. There are different options to include impact of the weighting factor. The first option that connects most closely to previous Eco-point studies is to incorporate an extra factor to value the habitat quality as described in §2.5.

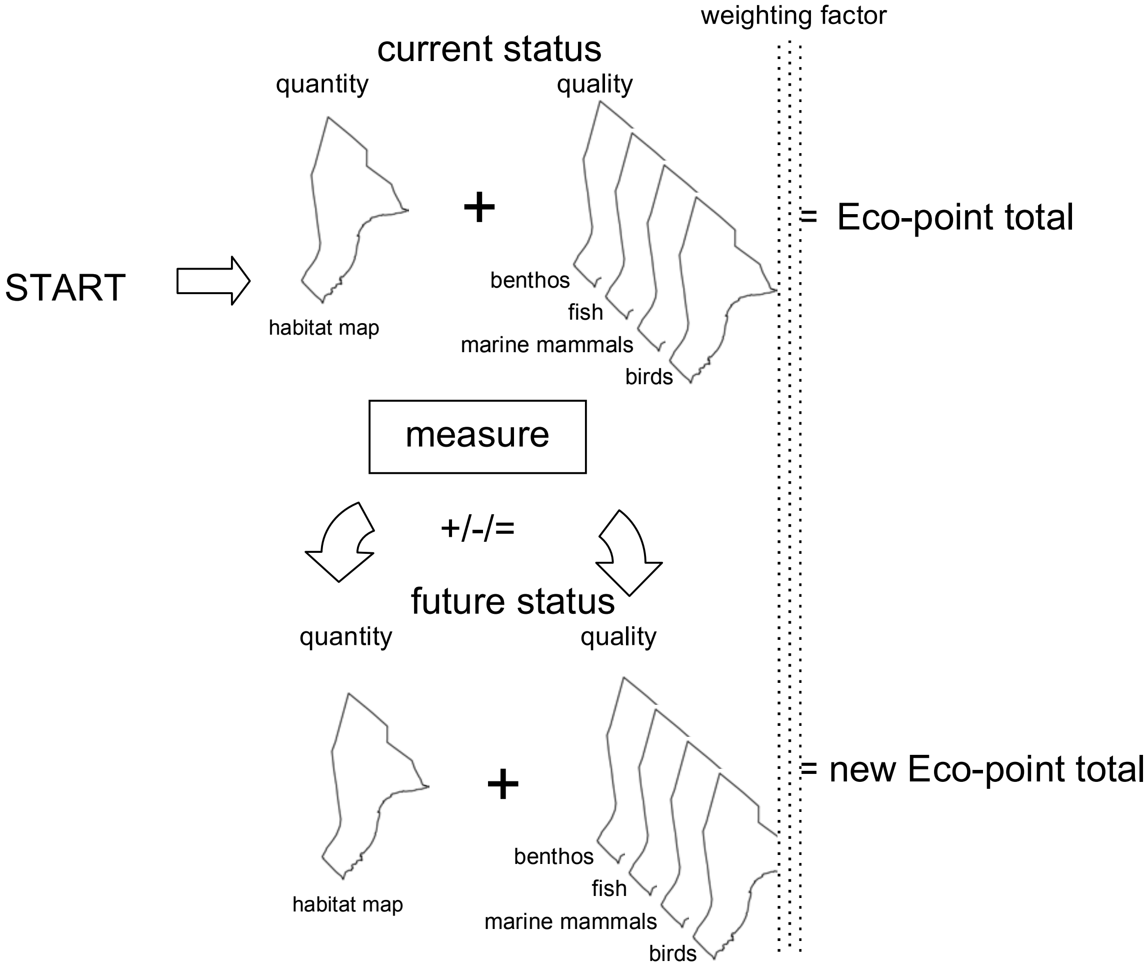

Figure 2.6: Principles of the Eco-point evaluation method. The current situation is assessed by combining a habitat map (quantity parameter) and maps of different metrics (quality parameters). Measures will act either positively (+), negatively (-) or indifferently (=) upon the quantity and quality of one or several habitats, resulting in an adjusted Eco-point total. Calculating adjusted Eco-point values can be used as a loop procedure.

2.6.2 Calculating Eco-points

In the Eco-point framework for the North Sea, Eco-points are calculated as follows:

- Eco-points = Habitat Area x Habitat Quality x Habitat rarity/Habitat fidelity.
- Area is defined by the size of that part of the North Sea, that is actually affected by the measure for which Eco-points are being calculated. The unit of measurement used is 100 km^2. So the area for a measure that influences 3000 km^2 of the North Sea is entered in the calculation as value '30' for quantity.
- The score for quality is pre-calculated in the following steps:

1) The effect of a measure on a specific metric is assessed and expressed in percentages of change. A bottom protection zone, for instance, may result in a 20% increase of benthos species richness.
2) For each species group, a mean habitat specific local quality increase is then calculated across all metrics. So if the quality score only one out of four metrics increases by 20%, the average gain for that species group (benthos in this case) is 5%. The quality score for benthos thus increases by 5% as a result of the measure.
3) Subsequently, an aggregated increase is calculated by averaging the mean quality scores across all four species groups (benthos, fish, marine mammals, birds). So if only benthos has increase by 5%, the aggregated quality score increases by 1,25% in this example.
4) The new aggregated quality score is the new value for quality in the Eco-point equation.

- A quality of 100% is defined in this study as the maximum obtainable value for a single metric per habitat in the current situation. Reference values (representing 100%) for habitat quality (cf. WFD) are subject to many discussions and are not available for the North sea (yet). Therefore the current situation is used as a reference (and starting point) by calculating the maximum value registered per metric per cell per habitat type. This value represents 100% quality for this specific metric in this specific habitat type. This fits to the MSFD objective for GES 1: ‘Biological diversity is maintained’.

- For the weighting factor we explored two possible definitions:

  1) The normalised habitat rarity index, calculated as described in §2.5.1 It is a factor that increases with habitat rarity.
  2) A factor based on the fidelity of species to certain habitat types (§2.5.2).

To calculate the gain in Eco-points that a measure will have, first the Eco-points are calculated based on the present aggregated quality score within the area affected by the measure. The habitat(part) in which the measure is carried out, determines the weighting factor. Subsequently, Eco-points are calculated with the altered quality scores as a result of the measure. The difference in Eco-points between the pre- and post-measure situation represent the gain of biodiversity due to this measure in a specific habitat.

If a measure comprises parts of several habitats, Eco-points are calculated for each habitat separately, using different area, quality and weighting factors. The sum of Eco-points then represents the total gain of a measure.

2.7 Application and fine tuning of the framework

2.7.1 Technical application

One particular advantage of the Eco-points method is that it is based on spatial data and therefore calculates the effects of measures at a local level. Furthermore using spatial data allows comparison of different scenarios at different locations (or habitats) where the impact of a measure can be calculated and visualised.

Data pre-processing consisted of translating spatial data to layers with similar spatial resolution (§2.7.2). The layers were added to a geodatabase, that was used as a basis for Eco-point calculations. Technical aspects of this method are described in appendix 5.

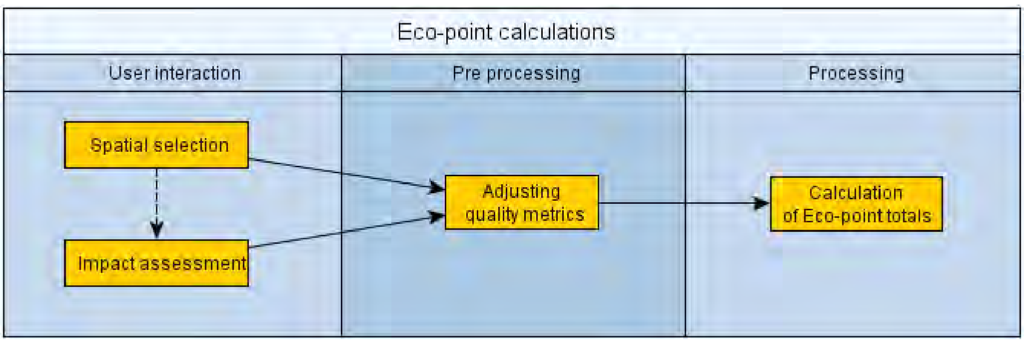

Figure 2.7 Schematic visualisation of the data-processing tool.

The basis of the technical application of the framework consisted of a database containing spatial data of habitat, quality metrices and a weighting factor. 4 steps were identified to calculate Eco-point totals (differences) (Figure 2.7 and 2.8):

1) Spatial selection
The area that is selected by the measure is selected (figure 2.8).

2) Impact assessment
Within the affected area, impact of the measure is assessed. This includes assessing quality changes per biodiversity metric and per habitat if more then 1 habitat is present in the selected area.

3) Adjusting quality metrics
Based on the impact assessment (step 2) the start-off values of quality metrics are adjusted within the selected area (step 1).

4) Calculating Eco-point totals
Based on the adjusted values of the quality metrics, new Eco-point totals are calculated.

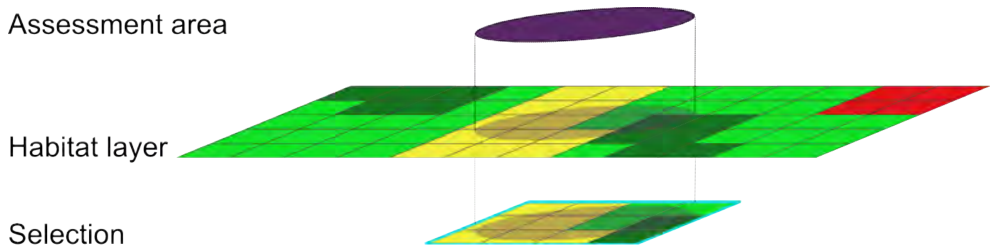

Figure 2.8 Spatial selection includes selecting habitat or metric layers on this same location.

2.7.2 Spatial resolution

In order to be able to calculate the different factors (quality, quantity and weighting factor) at the same level, we decided to use all data on the level of assessment areas of 5x5 km. This resulted in the use of 2367 gridcells for the DCS. In this way spatial accuracy for all factors is 5x5 km at its maximum. Both polygon and larger grid data were gridded to this level. Total surface area of the study area is 59175 km^2.

2.7.3 Preparation of the habitat map (factor 1)

First of all original EUNIS level 3 classes were grouped into new habitats according to table 2.1. The new map (polygon, figure 2.9.a) was gridded to 5x5 km. Since the KRM does not cover the transitional and coastal waters (covered by the WFD) they were excluded. To prevent that the rarer habitats will vanish if largest surface area is used in the gridding process, we decided to grid according to “rarest habitat”. For this procedure the normalised weighting factors (table 2.4) were used. Figure 2.9b shows the final grid map.

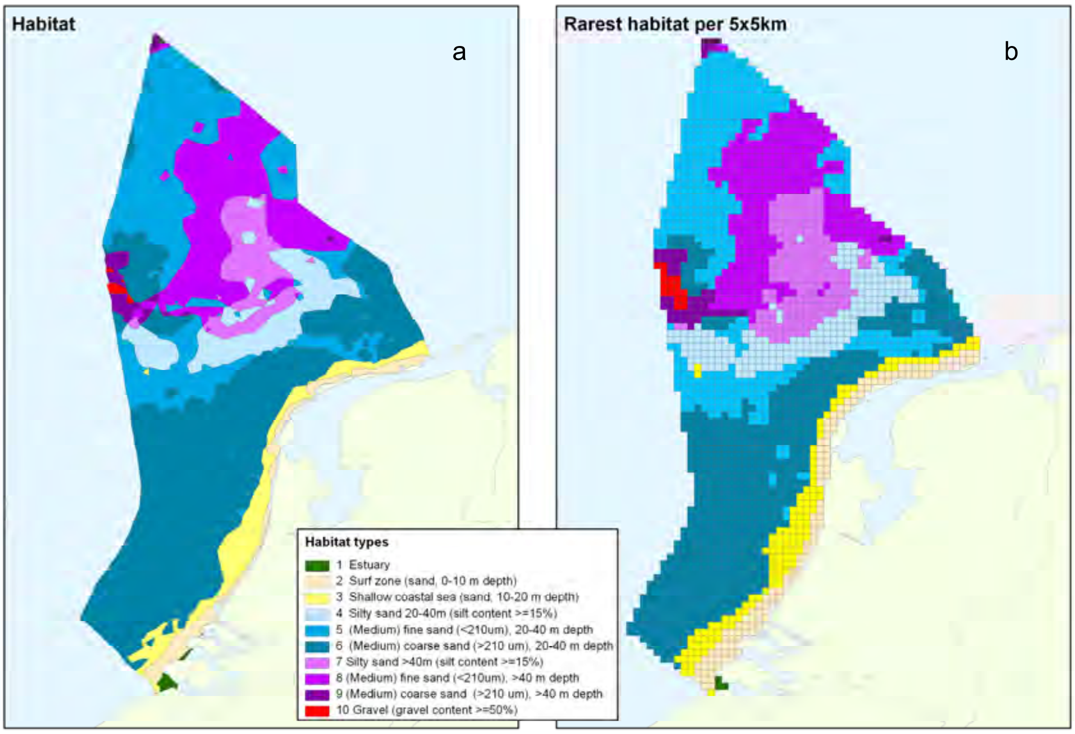

Figure 2.9 Habitat map. a. new habitats (see table 2.4 for aggregation) b. Gridded habitat maps. (data source: IMARES)

2.7.4 Preparation of biodiversity metrics and maps (factor 2)

For the selected biodiversity metrics different data were available. For some metrics only rescaled data were available, for other data more detailed, continuous data were available (table 2.5). Both in the rescaled data and the continuous data, maximum quality was variable (table 2.5).

Table 2.5 11 biodiversity metrics that were selected for this study, data type, range of maximum values per habitat in current situation (set to a quality of 100%). Data derived from Bos et al. 2011).

Species group	Metric	Data type	Range (max)
Benthos	density	rescaled	1-9
	biomass	rescaled	4-8
	rarity	rescaled	3-4
	large species	rescaled	3-7
	species richness	rescaled	1-9
Fish	rarity	continuous	0,03-0,07
	large ind. within species	continuous	7-16
	species richness	continuous	39-50
	large species	continuous	4-10
Birds	bird value	rescaled	9-10
Marine mammals	density	sum class	10-12

Few steps were necessary in order to scale metric maps to 5x5 km grids:

Benthos. For benthos point data were kriged using 4 neighbouring points. Restrictions of interpolations between habitat types were obtained by cokriging with the EUNIS habitat map of de Jong (1999) (see Bos *et al.* for details). Kriged data resulted in several values per assessment area. Maximum value was used to obtain the value for each assessment area. Areas containing 0 values were omitted when calculating habitat quality and treated as nil values.

Fish For fish data were obtained on the scale of 1/9 ICES triangle. Data were gridded to the scale of 5x5 km. A total of 94 grid cells contained zero values for species richness, whereas large species did contain values. These areas were omitted when calculating habitat quality and treated as nil values.

Marine mammals are available on 5x5 km scale.

Birds For birds data are available on 5x5 km scale. However few gaps exist. Interpolation was executed using 8 neighbouring cells and fewer if present (figure 2.9). For one cell this procedure had to be repeated with interpolated values.
The metrics that are used in chapter 3 all are available on a DCS scale in and displayed in appendix 6.

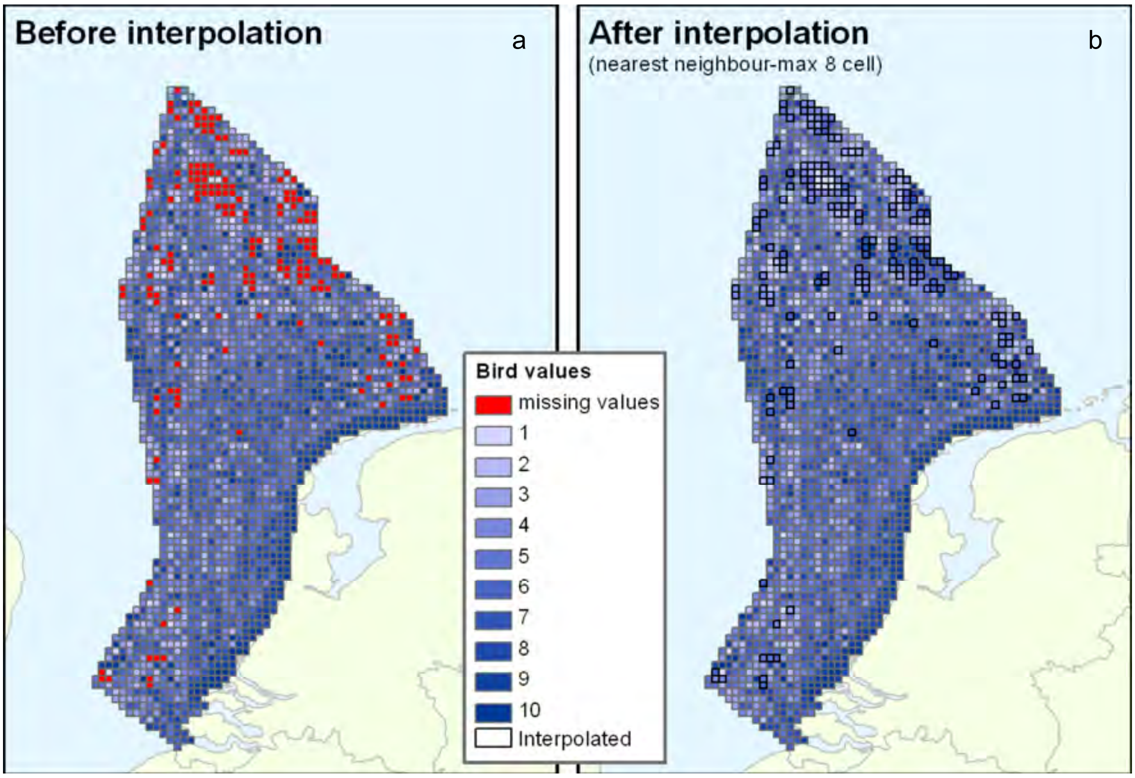

Figure 2.9 Bird value map. a. original map with missing values b. map with interpolated values. (data source: IMARES)

2.8 Sensitivity analysis

2.8.1 Sensitivity of Eco-point output

The Eco-point methodology is based on linear relationships between the factors included (Eco-point total = $\sum_{all\ habitats}$(Area × Quality × Weighting $factor_{per\ habitat}$). Sensitivity analysis of the results reveals the effects of this relationship (figure 2.10). Differences in the sensitivity per habitat type result from the differences in surface area and quality in the current situation (table 3.2).

Similar to the approach in pilot 'Afsluitdijk' (Wessels & Jaspers 2010) sensitivity analysis was based on Eco-point-differences (Δ-Eco-points) considering a change per 25 km^2, per 10% quality change and 10% weighting factor difference. The results of this analysis indicate that Eco-point calculations are most sensitive to a change in habitat quality (figure 2.10). In this analysis the weighting factor is habitat rarity (§2.5.1).

Habitat type 10 (Gravel) turns out as the most sensitive habitat. A quality difference of 10% for this habitat results in Δ-Eco-points of 300 (figure 2.10). This may be considered as threshold value for a significant difference in Eco-points as a result of measures. This approach corresponds to the sensitivity analysis in Wessels & Jaspers (2010). In their study a threshold value of 1000 Δ Eco-points was estimated as significant.

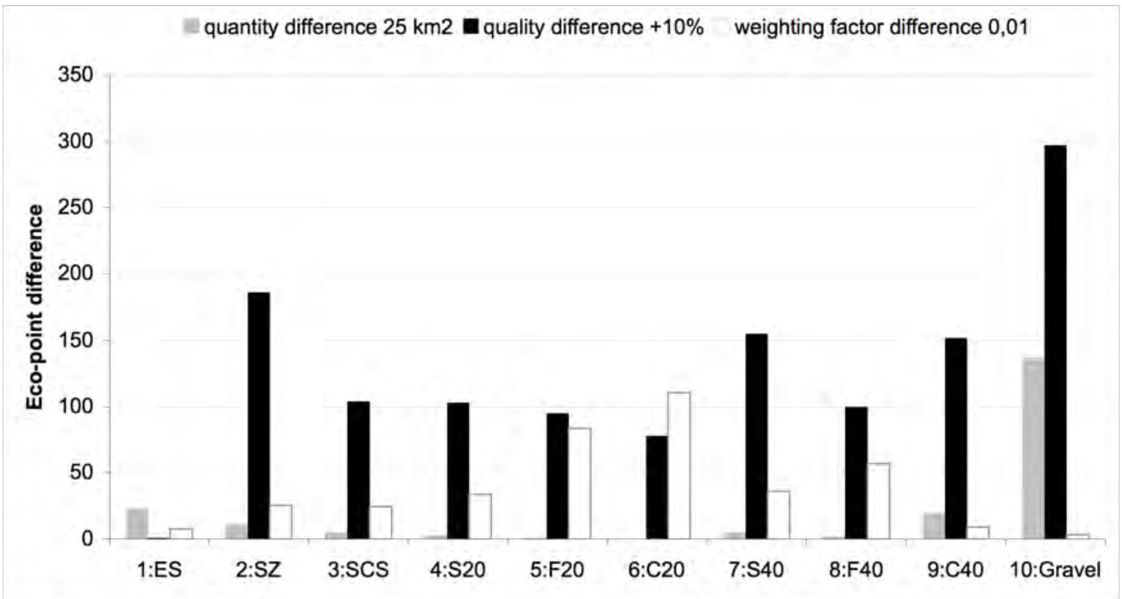

Figure 2.10. Eco-point total differences (ΔEco-points) due to changes in each of the 3 factors, based on current Eco-point calculations (table 3.2). The weighting factor in this analysis is defined as habitat rarity.

2.8.2 Sensitivity for continuous versus rescaled data

In this study we used both continuous and rescaled data (table 2.5) because these were the only readily available data on biodiversity on the DCS. Most appropriate are continuous data, as they are easier to interpret in relation to measures, but these were not available for all species groups. For fish, both rescaled and continuous data were available. We used both types of data data for fish to analyse the sensitivity of Eco-point calculations for the type of data.

Continuous or basic data are derived from field measurements whereas rescaled data a breakpoint has been set for values that belong to different classes. To be able to compare and combine different metrics values were rescaled on a scale of 1-5 to obtain 5 classes, using the 20th, 40th etc. percentile as a breakpoint. Within a class all values are the same. Translating these values into Eco-point quality results in different quality estimates: quality is a value between 0 and 1 and derived by dividing a value by the maximum value.

This is illustrated by an example where of four fish metrics (large individuals, large species, rarity and species richness) both continuous and rescaled data are available. The rescaled fish-data are divided into 5 classes. Rescaled data result in a quality of either 0,2, 0,4 0,6 0,8 or 1 with 0,2 as the lowest obtainable quality. When the average quality per habitat is compared to quality derived from continuous data different outcomes are observed (fig. 2.11). For 3 metrics rescaled data provide a higher quality value with a maximum difference of 0,5. For species richness continuous data result in a higher quality up to 0,2 maximum difference. In 25% of the cases no difference was observed. When this is true for all species groups, rescaled data generally lead to an overestimation of Eco-points.

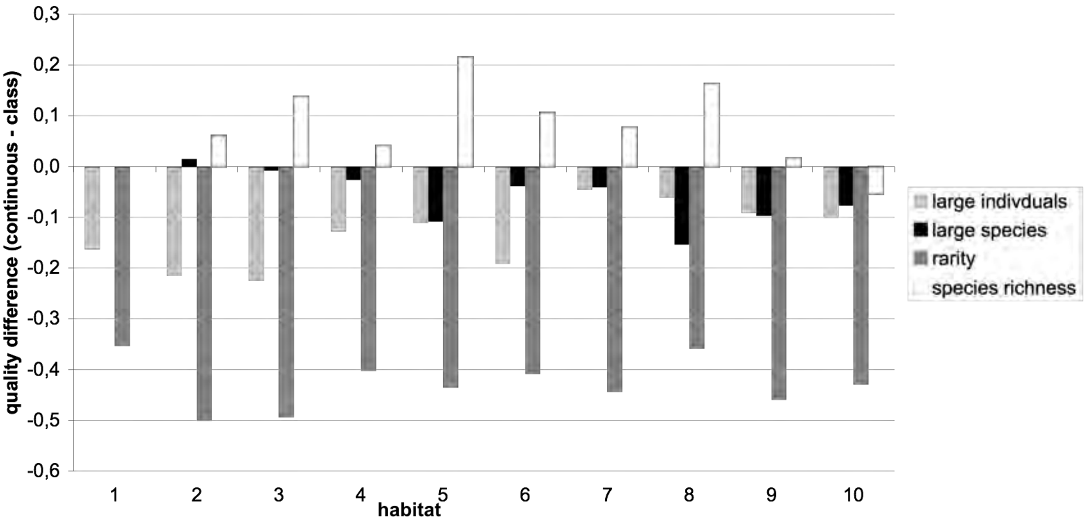

Figure 2.11 The mean difference in Eco-point quality (0 to 1) per habitat type, comparing continuous and rescaled data for fish metrics. The weighting factor in this analysis is defined as habitat rarity. Positive values indicate a higher value for continuous data, negative values a higher value for rescaled data.

3 Results

The calibrated Eco-point framework was tested in two case studies with potential MSFD measures. The ecological impact of these measures was estimated by expert judgement and should be considered as a test case. In this exercise we implemented data derived from Bos *et al.* (2011). We tested both weighting factors Habitat rarity and Habitat fidelity. Starting point is the current status of the North Sea.

3.1 Current eco-points

3.1.1 Current quality

Based on 11 biodiversity metrics, the current quality of each habitat has been calculated (Table 3.1). This gives an indication of quality differences between habitats. The highest current quality is observed in the estuary, with high quality values for all species groups.

Table 3.1 Average quality of 10 habitats (Total) quality (in %) per metric and average per species group (benthos, fish, marine mammals, birds). Maximum quality is scaled to 100%.

habitat		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
biodiversity metric		ES	SZ	SCS	S20	F20	C20	S40	F40	C40	Gravel
benthos	density	100	58	52	70	65	39	81	79	58	68
	biomass	100	74	71	73	57	46	85	71	71	92
	rarity	100	80	86	72	75	53	88	81	85	99
	large species	100	95	91	75	81	55	89	84	89	97
	species richness	100	44	38	75	69	35	87	88	75	75
benthos total		*100*	*70*	*68*	*73*	*69*	*46*	*86*	*81*	*76*	*86*
fish	rarity	100	22	22	28	36	19	34	31	35	38
	large ind. within species	100	60	63	68	65	57	57	53	57	100
	large species	100	64	68	71	57	51	73	59	61	63
	species richness	97	92	89	85	78	80	83	77	84	88
fish total		*99*	*60*	*61*	*63*	*59*	*52*	*62*	*55*	*59*	*72*
marine mammals	density	100	96	87	80	85	85	80	76	92	96
marine mammal total		*100*	*96*	*87*	*80*	*85*	*85*	*80*	*76*	*92*	*96*
birds	bird value	85	85	64	60	47	51	53	47	54	58
bird total		*85*	*85*	*64*	*60*	*47*	*51*	*53*	*47*	*54*	*58*
Total		**96**	**78**	**70**	**69**	**65**	**58**	**70**	**65**	**70**	**78**

Maximum quality

For estimating the effect of measures (§3.4 and §3.5), a maximum quality level per habitat type has to be defined (reference or 100%). In this study the maximum quality of a habitat type for a specific metric is set to the maximum value of that metric within that habitat type in the current situation. This value is set to 100%. All values are scaled accordingly. In the presented case studies the predicted effects of measures on the current quality is assessed per metric, with the defined maximum quality level scaled to 100%.

3.1.2 Calculation of current Eco-points

Based on surface area, habitat quality (table 3.1), habitat rarity (table 2.4) and habitat fidelity (table 2.4), Eco-point totals of each habitat have been calculated for the present situation (Table 3.2 and 3.3). This gives an indication of differences between habitats and their contribution to total North Sea Eco-points. Due to a policy decision, estuary is mainly part of the WFD instead of the MSFD, which explains its minimal contribution to the Eco-point total. Using habitat rarity as weighting factor habitat 10 (gravel) is a major contributor due to its rarity, whereas habitat 2 is a major contributor due to its large surface area and high quality relative to other habitats (Table 3.2). Using habitat fidelity as a weighting factor habitat 6, followed by 5 and 8 are major contributors, due to their large surface area (table 3.3).

Table 3.2 Average Eco-points of 10 habitats and total points for the DCS based on surface area, quality and habitat rarity.

habitat		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
factor		ES	SZ	SCS	S20	F20	C20	S40	F40	C40	Gravel
1. quantity	(area km2)	75	3225	3475	4950	12800	18975	5125	8800	1325	425
2. quality	(table 6.1)	96	78	70	69	65	58	70	65	70	78
3. weighting factor	(habitat rarity)	0,24	0,58	0,30	0,21	0,07	0,04	0,30	0,11	1,15	7,00
	Eco-points	**17**	**1444**	**722**	**717**	**618**	**460**	**1087**	**643**	**1074**	**2320**
Total											**9102**

Table 3.3 Average Eco-points of 10 habitats and total points for the DCS based on surface area, quality and habitat fidelity.

habitat		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
factor		ES	SZ	SCS	S20	F20	C20	S40	F40	C40	Gravel
1. quantity	(area km2)	75	3225	3475	4950	12800	18975	5125	8800	1325	425
2. quality	(table 6.1)	17	1444	722	717	618	460	1087	643	1074	2320
3. weighting factor	(habitat fidelity)	*n.a.*	0,84	0,84	0,7	0,9	0,99	0,81	0,85	*n.a.*	2,06
	Eco-points		**2105**	**2035**	**2390**	**7506**	**10989**	**2914**	**4832**		**683**
Total											**33454**

3.2 Selection of measures

Basic input for the case-studies are the MSFD measures, specified by the Ministry of Infrastructure & Environment. Reinhard *et al.* (2011) selected measures from this list that are considered in the cost benefit analysis (appendix 7). Their study also provides a detailed description of several variants of these measures and their impact. They relate only one of the measures directly to biodiversity: “Introducing hard substrate items in bottom-protection zones”. Most MSFD measures only relate to the pressure litter and address GES 10. Therefore for the case studies we selected a litter-related measure as well. The interpretation and assessment of effects of these measures are described in § 3.4 and 3.5.

To quantify the effect of measures in terms of Eco-points, input is needed on the expected effect of these measures on the selected species group specific metrics (see section 2.6.2). Reinhard *et al.* (2011) estimated effectiveness of measures on GES by expert judgement at a more general level, which is inappropriate for application in a quantitative method such as the Eco-point methodology. A reliable and comprehensive assessment of the ecological impact of measures may be based on elaborate literature study and/or expert consultations. This was beyond the scope of this study, and we therefore provisionally interpreted the ecological impact of the considered measure by expert judgement and available literature (e.g. Bouma & Lengkeek 2008; Lengkeek & Bouma 2010; Lengkeek *et al.* 2011). Since this study concerns an exploration of the method, these provisional numbers can be replaced by more reliable measure-impact-assessments at any stage in the future. Also (the interpretation of) the measures can be replaced by other (interpretations of) measures.

3.3 Case study – sea floor restoration

3.3.1. Definition of the measure

Reinhard *et al.* (2011) report that the effect of introducing hard substrate for preventing sea bottom disturbance as an enforcement measure is questionable. For example, introducing a ring around the Cleaver Bank requires a large amount of rocks. Also the size of these rocks has to be significant, for otherwise they are expected to be covered with sand within a few years (van Moorsel & Waardenburg 2001). The effect of this measure is that the presence of stones impedes fishing and benthic species colonize the newly introduced hard substrate. The substrate type and the exact location determine the impact on biodiversity.

Application of this measure with the aim of introducing an artificial reef, resulting in higher biodiversity at a local scale, could be an option, but seems not realistic, at least not for a reef of a significant size. In this case study we interpreted the measure as follows:

- The boulders / stones remain their position on top of the sediment and do not sink in the seabed;
- The stones boulders are large enough so that they are not moved by rough sea conditions.
- Five percent of the surface area will be covered by boulders. This does not change the actual type of the habitat;
- As a result the area is effectively closed to fisheries;
- We explored the effect of shifting locations by defining two scenario's of measures in two different habitat types (figure 3.1)
- For both scenario's we defined an area of implementation of 400 km^2 for all metrics.
- The area of influence is assumed equal to the area of implementation, i.e. 400 km^2.

3.3.2 Effect of the measure on habitat quality

The measure 'introducing hard substrate' results in a local increase of biodiversity. Main impact factors are: 1) the introduction of hard substratum as a habitat element and 2) the obstruction of fisheries. We assumed that an increase of 5 % of hard substratum does not change the habitat type. Sandy habitat includes hard substrate elements, such as relicts of peat banks or shipwrecks, that are not mapped as a separate habitat types. For de definition of the habitat type gravel a surface area of > 50% of gravel is defined as bottom line (Bos *et al.* 2011). We assessed the effects on the different metrics of the measure described above as follows (for results see table 3.4):

Benthos

Hard substrate generally has a much higher density of benthic life than soft sediments, with the exception of some shellfish banks that generate very high densities in soft sediment. In addition, hard substrate habitats are species-rich, and mostly contain different species than can be found in soft-sediments (Lengkeek *et al.* 2011). Generally, introducing hard substrate will increase benthic density, biomass and species richness drastically. Furthermore, where bottom-disturbing fisheries are excluded, shellfish density in soft substrates may increase. In addition, this will lead to better opportunities for long-lived and larger species. It is expected that the combined effect of introducing hard substrate and exclusion of fisheries result in a maximum achievable state for all five benthos metrics (density, biomass, rarity, large species, species richness) in these habitats (in this case study: (medium) fine sand 20-40m (habitat type 5) and gravel (habitat type 10). The definition of this maximum achievable state is based on maximum habitat quality as reported for a specific habitat type (see §2.7.4).

Fish

In both habitats, closure to fisheries will result in improvement of most metrics, but this effect will be limited by the small scale of the measure. Fish may reach higher body size within the protection zone. Species such as cod or some elasmobranchs, can be particularly attracted to hard substrate habitats and stay in close proximity of the boulders for elongated periods of time (Lindeboom *et al.* 2011). Therefore, local quantities of large individuals may increase. However, because this concerns a relatively small measure, most individuals will eventually swim out of the zone and get caught. The effect on the metric 'large individuals' is therefore positive but limited. This mechanism will occur for rarity, large individuals and large species.
Species richness however, is a different case. In habitat 5 ((medium) fine sand 20-40m), hard substratum is a newly added habitat. This will result in a dramatic increase in species richness because it attracts typical hard substrate species such as for instance wrasse species that where previously absent. In habitat 10 (gravel) this additive effect is much less, because hard substrate already exists in this habitat, and the current state for species richness is already high.

Marine mammals and birds

The measure of introducing hard substrate is not expected to have significant impact on birds or marine mammals. Although densities of shellfish may increase, depths in habitat type 5 and 10 are generally to deep (over 20m) for shellfish eating birds. Although fish densities will increase, the scale of the measure is too small to significantly affect fish eating marine mammal populations. At least, any possible relationship between predicted increases in fish and increases in marine mammal density is too uncertain to quantify at this stage. Nevertheless a positive effect of this measure may be expected on both species groups as it increases food density.

The size of the impact area

It is possible that the impact area of a measure is larger or smaller than the area in which the measure physically takes shape. When, for instance, fish stocks increase locally as a result of fisheries exclusion, a ‘spill over’ effect may be expected. This means that fish that reach higher densities in the targeted area swim outside this area and increase density in the surrounding areas too. Especially for fish, however, an increased fishing intensity close to marine protected areas or other areas where increased fish stocks can be expected, often compensates this effect. This can certainly be expected in the heavily fished North Sea.

So, fish stock increases must be very substantial before any ‘spill over’ effect can be expected to result in measurable increases of stock outside the area closed for fisheries. Measurable ‘spill over’ effects are therefore not expected as a result of this measure, in neither habitat 5 or 10. We therefore assume that the size of the impact area is equal to the implementation area.

Table 3.4: Assessed effect on habitat quality of MSFD measure ‘sea floor restoration’ on metrics for two different locations (see figure 3.1). Indicated is the predicted effect of the quality indicator (in %), where positive values indicate improvement vs negative values that indicate degradation. Scenario 1 is located in habitat type 5: (medium) fine sand 20-40m (habitat type 5), scenario 2 is located in habitat type 10: gravel.

Species group	Metric	Present situation habitat 5	Effect habitat 5	Post-measure habitat 5	Present situation habitat 10	Effect habitat 10	Post-measure habitat 10
Benthos	density	76	24	100	66	34	100
	biomass	84	16	100	97	3	100
	rarity	98	2	100	98	2	100
	large species	88	12	100	73	27	100
	species richness	63	37	100	92	8	100
Fish	rarity	23	10	24	39	10	49
	large ind. within species	27	10	55	100	10	100
	large species	82	10	67	97	10	100
	species richness	70	30	100	89	12	100
Marine mammals	density	82	0	48	97	0	89
Birds	bird value	37	0	78	59	0	59
Total		**62**		**70**	**78**		**84**

3.3.3 Results for sea floor restoration

For two scenario's (Fig 3.1) the the new quality was established for each metric based on table 3.4, resulting in a locally increased habitat quality (see Fig 3.2). Averaging the values of 16 assessment areas of 5 x 5 km resulted in an increase in habitat quality from 62 to 70 in scenario 1 and an increase of 78 to 84 in scenario 2 (Table 3.5). Eco-point totals increased with 3 points in scenario 1 (habitat 5) and 150 Eco-points in scenario 2 (habitat 10). Total Eco-points are 9104 (scenario 1) and 9252 (scenario 2) (table 3.5). Compared to the total number of Eco-points in the current situation (9102), the first effect corresponds to an increase of 0.005%, whereas the effect of scenario 2 corresponds to a 1,6 % increase.

Table 3.5 Eco-point calculations for 2 different scenarios. NB: when cells are already at 100% quality, the effect of measures per metric (in %) may be smaller than assessed in table 3.4.

Factor	**Scenario**			**1**		**2**
1	**Area**		**400**	**400**	**400**	**400**
	biodiversity metric		before	after	before	after
	benthos	density	76	100	66	100
		biomass	84	100	97	100
		rarity	98	100	98	100
		large species	88	100	73	100
		species richness	63	100	92	100
	benthos total		*82*	*100*	*85*	*100*
	fish	rarity	23	33	39	46
		large ind. within species	27	37	100	100
		large species	82	82	97	97
		species richness	70	100	89	100
	fish total		*51*	*63*	*58*	*86*
	marine mammals	density	82	82	97	89
	marine mammal total		*82*	*82*	*97*	*89*
	birds	bird value	37	37	59	59
	bird total		*37*	*37*	*59*	*59*
2	**Quality (total)**		**62**	**70**	**78**	**84**
3	**Habitat fidelity**		**0,07**	**0,07**	**7**	**7**
	Eco-point total		18	21	2196	2346
	Eco-point gain			**3**		**150**
	Eco-point North sea total		9102	9107	9102	9252

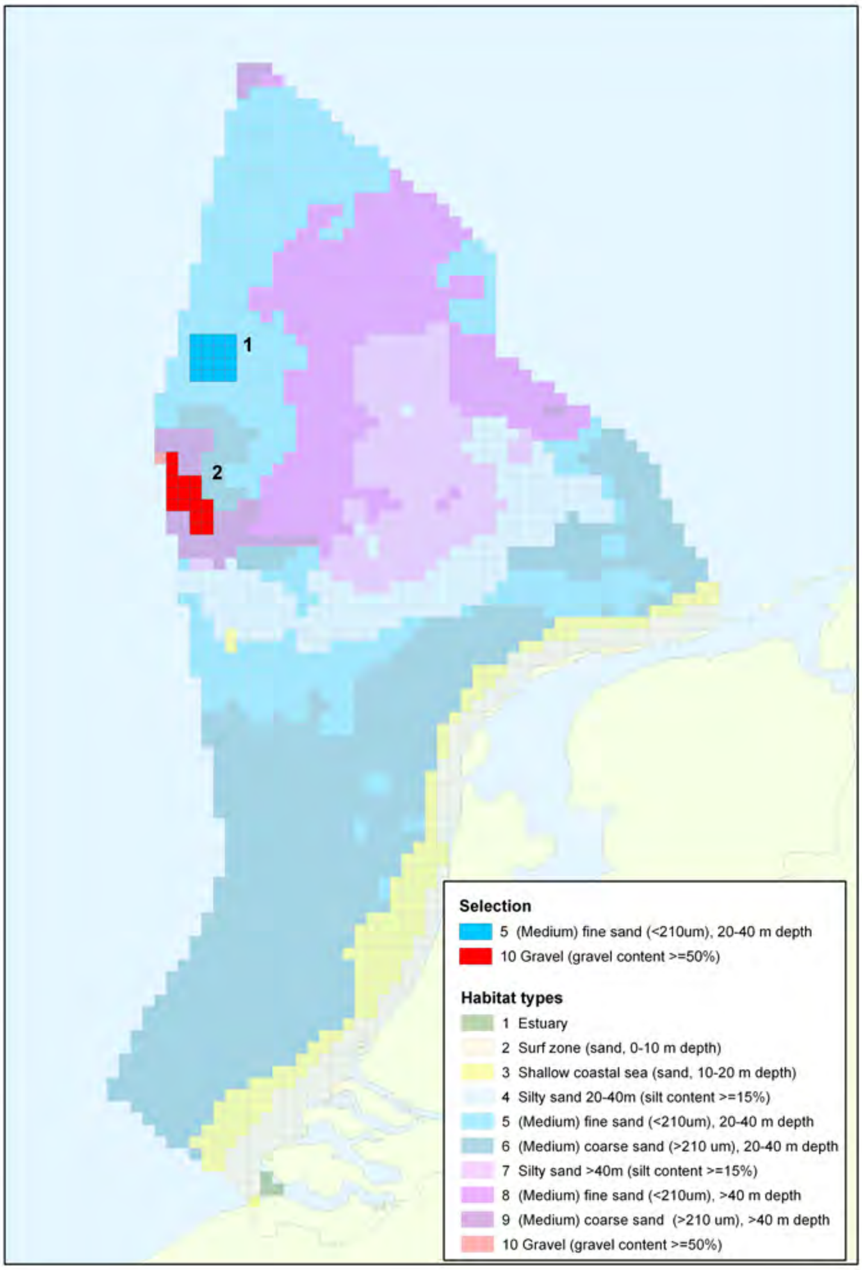

Figure 3.1 Locations of implementing measures in scenario 1 (1) and 2 (2). (data source: IMARES).

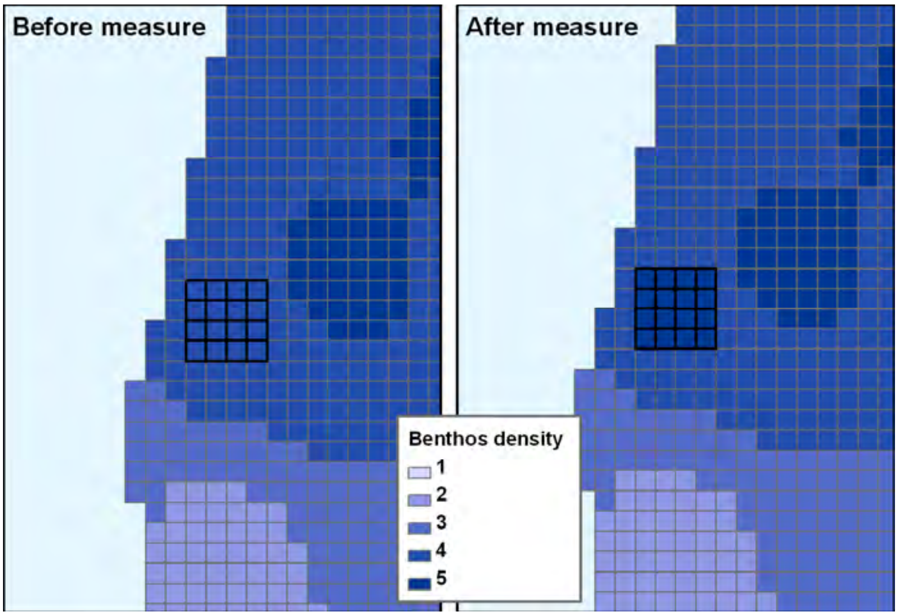

Figure 3.2 Example of quality difference for Scenario 2 (habitat 5, 400 km^2): benthos density before and after the measure. Affected area is outlined in black. (data source: IMARES).

3.4 Case study – litter reduction

3.4.1 Definition of the measure

In this case study we interpreted the measure litter reduction as follows:
Measures to reduce litter in the North Sea ecosystem will result in effective removal of all human originated debris in the North Sea including plastic materials and micro-plastics. The impact area is the entire study-area (DCS).

3.4.2 Effect of the measure on habitat quality

The litter-reduction measures in MSFD primarily focus on GES 10. Effects on biodiversity of the related pressure are not clear, and therefore effects of measures are difficult to interpret. Nevertheless, since the Eco-point method concerns biodiversity we attempted to assess the effect of litter reduction on the different metrics for biodiversity.

Marine litter, in particular plastic waste, represents a global environmental problem. For a variety of marine animal species, mortality or injury has been reported as a result of entanglement, or ingestion of plastic debris. Entanglement in marine debris has been reported for at least 20 pinniped species, 14 cetaceans, all 7 species of sea turtles and more than 56 % of all marine and coastal bird species (Katsenevakis 2008).

Ingestion of marine litter has been reported in at least 32 species of cetaceans, all species of marine turtles, more than 111 species of seabirds and many species of fish (Katsenevakis, 2008). In the North Sea specifically, 95% of Fulmars are estimated to have plastic in their stomach (van Franeker *et al.* 2005).
When plastic debris remains in the marine environment for long enough, it breaks down to micro-plastics. These plastics can enter the very base of the foodweb, as they can be ingested by filter feeding organisms such as shellfish.

In spite of the scale of this problem, its impact on biodiversity is particularly difficult to quantify. It is demonstrated that individuals can die as a result from entanglement. All sorts of problems have been suggested as a consequence of ingestion. Impacts on population levels, however, have not been demonstrated (not for North Sea species).
The high number of 95% of fulmars with plastic in their stomach is certainly alarming, but it is not actually demonstrated that this has consequences for the distribution or density of the species.

Due to the lack of clear evidence for impacts of marine litter on biodiversity to this date, the impact of reducing litter in the North Sea on any biodiversity metric, should be considered as zero. Again, this does not mean that there are no effects to be expected, but it is at this stage not possible to give any meaningful indication of the impact on biodiversity indicators.

3.4.3 Results for litter reduction

Since there is no assessment possible of the effect of litter reduction on any metrics, the number of Eco-points to be gained with this measure is 0. The total number of Eco-points calculated corresponds to the number of Eco-points in the current situation (table 3.6), which is 9102.

This outcome, however, is no indication that the marine debris problem is non-existing, but an indication that this measure should not be evaluated in the view of GES descriptor 1 biodiversity.

Table 3.6 Eco-point calculations for litter reduction.

			Habitat type (N°)									
Factor			**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	**Area (km^2):**		**75**	**3225**	**3475**	**4950**	**12800**	**18975**	**5125**	**8800**	**1325**	**425**
	benthos	density	100	58	52	70	65	39	81	79	58	68
		biomass	100	74	71	73	57	46	85	71	71	92
		rarity	100	80	86	72	75	53	88	81	85	99
		large species	100	95	91	75	81	55	89	84	89	97
		species richness	100	44	38	75	69	35	87	88	75	75
	benthos total		*100*	*70*	*68*	*73*	*69*	*46*	*86*	*81*	*76*	*86*
	fish	rarity	100	22	22	28	36	19	34	31	35	38
		large ind. within species	100	60	63	68	65	57	57	53	57	100
		large species	100	64	68	71	57	51	73	59	61	63
		species richness	97	92	89	85	78	80	83	77	84	88
	fish total		*99*	*60*	*61*	*63*	*59*	*52*	*62*	*55*	*59*	*72*
	marine mammals	density	100	96	87	80	85	85	80	76	92	96
	marine mammal total		*100*	*96*	*87*	*80*	*85*	*85*	*80*	*76*	*92*	*96*
	birds	bird value	85	85	64	60	47	51	53	47	54	58
	bird total		*85*	*85*	*64*	*60*	*47*	*51*	*53*	*47*	*54*	*58*
2	**Total quality**		**96**	**79**	**70**	**75**	**70**	**63**	**76**	**72**	**76**	**79**
3	**Habitat fidelity**		**0,24**	**0,58**	**0,3**	**0,21**	**0,07**	**0,04**	**0,3**	**0,11**	**1,15**	**7**
	Eco-point total		17	1444	722	717	618	460	1087	643	1074	2320
	Eco-point gain		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	Eco-point North sea total											9102

4 Societal valuation

The Eco-points method was proposed as a method to quantify the effects on nature (i.e. biodiversity) of spatial developments and measures, to be used in Cost-Benefit Analyses (CBA's). In a CBA these ecological effects are weighted against economic values (expressed in monetary units). However, the valuation of ecological values (including biodiversity) is dependent on societal value systems. In their Nature Outlook 2011-2040 the PBL Netherlands Environmental Assessment Agency explores scenarios for four such societal value systems and their impact on nature over the next 30 years (PBL, 2011). This chapter describes these four scenarios and discusses if and how the Eco-point methodology can be used in a CBA for the MSFD to incorporate these societal value systems.

4.1 The four scenarios of the Nature Outlook 2011-2040

The four scenarios represent societal value systems. This means that the principles applied within the scenarios reflect the way people think about nature and the decisions they make when confronted with choices between nature and other societal-economic factors. As the value attributed to nature differs between people, so the scenarios differ in the priority that is given to developments in favour of nature or in favour of other objectives. The four scenarios are: Vital nature, Recreational nature, Functional nature and Flexible nature.

The scenarios were developed for the European area of the Netherlands only. The area of the Dutch Continental Shelf (DCS) was included in the scenarios. The scenarios were developed with and commented on by stakeholders. The spatial translation for each of the scenarios is given in a schematized way in figures 4.1 to 4.4. Here a short description of the four scenarios is given with a focus on the North Sea. The following descriptions and considerations of the four scenario's result mainly from the second workshop of the Nature Outlook 2011 (Dammers 2010). For further details, see PBL (2011) and Wiersinga et al. (2011).

1. Vital nature

The focus on wilderness infers minimising interference to the nature of the North Sea. The undisturbed natural processes give shape and meaning to the ecosystem and habitats. The natural processes of water, wind and sediments ensure biodiversity. Human intervention can mimic natural processes through the creation and removal of sandbanks. This includes indigenous nature with a high intrinsic value. It is based upon large-scale areas of sufficient size to support sustainable populations. Measures focus on protection and exclusion. For ecological values that are of interest from a European perspective, restoration may also be a consideration before protection. Shared use of the North Sea is in this scenario only possible when there is no effect on biodiversity.

Considerations:

- Aim for a large area of fresh-salt water gradients.
- Fisheries based on ecosystem approach and Maximum Sustainable Yield (MSY).
- Sand workings are undesirable.
- Zones purely for nature.
- Diverse fish stocks with large predators.
- Special attention for rays, seaweeds and fauna of hard substrates.
- Unhindered migration for birds, fish and marine mammals.
- Restoration or creation of hard substrates for ecological development.
- Protection of oysterbeds because of their high biodiversity.
- Use of indicator species for migratory species and entire ecosystems: harbour porpoise, white-beaked dolphin, shell banks, seaweeds, (thornback) ray, sabellaria, anemone, guillemot, terns, grebes, divers, eider and little gull.
- Also consider the quality of the North Sea in general, not only in the interesting areas.

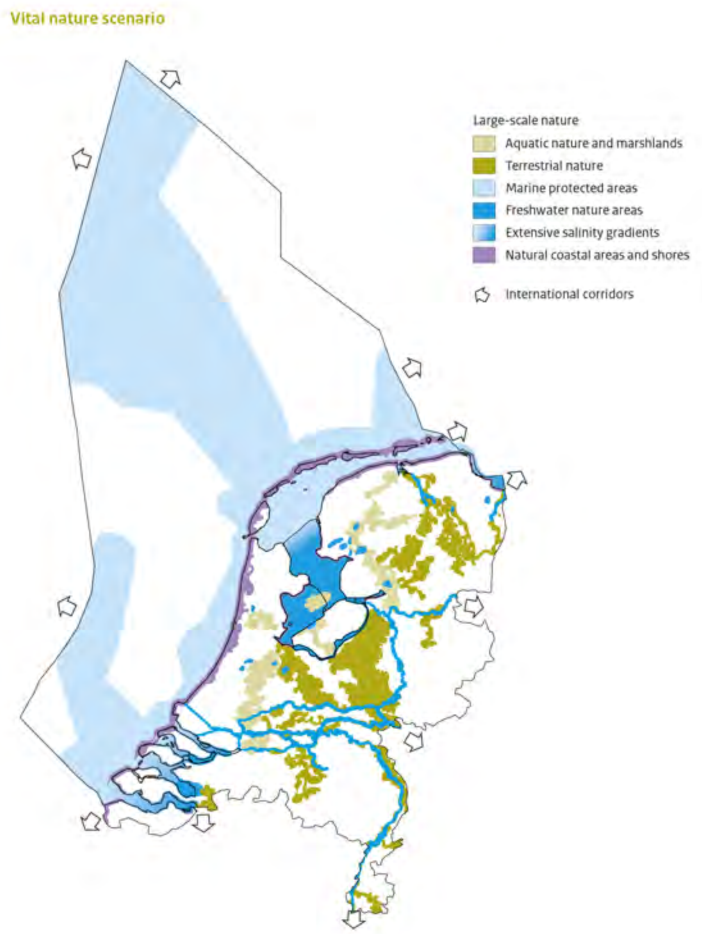

Figure 4.1 Map of vital nature scenario (source: PBL).

2. Recreational nature

From a pure aesthetic view of nature, the North Sea offers people many beautiful and pleasant experiences. People make use of the sea for pleasure and enjoy the presence and experience of nature. It does not always follow that the areas with highest aesthetic value have the highest value for wildlife. The most accessible and arguably most beautiful areas of the North Sea, the dunes, wide sandy beaches and shallow coastal zone receive the most attention. A natural coast is desirable as it provides beauty and the differences during the tidal cycle are clear. An open horizon is important for the experience of a pure sea and that shellfish and young fish are protected is a bonus. Spectacular species and their habitats must be protected to ensure they persist into the future. The 'big five' of the North Sea are harbour porpoise, cod, thornback ray, dead man's fingers and gannet. These five species represent the main species-groups of the North Sea: marine mammals, bony fish, cartilaginous fish, corals and birds. Even underwater at dive sites nature must be conserved and easily accessible.

Considerations:

- Wind farm and aquaculture are valuable for people.
- Tourist attractions at the coast (harbours, piers).
- Tourist attractions at sea (bird islands, 'whale-watching' from disused platforms).
- Recreational use of interesting fish stocks such as cod and seabass.
- Cultural and historical education of the sea (former fish preserving methods).

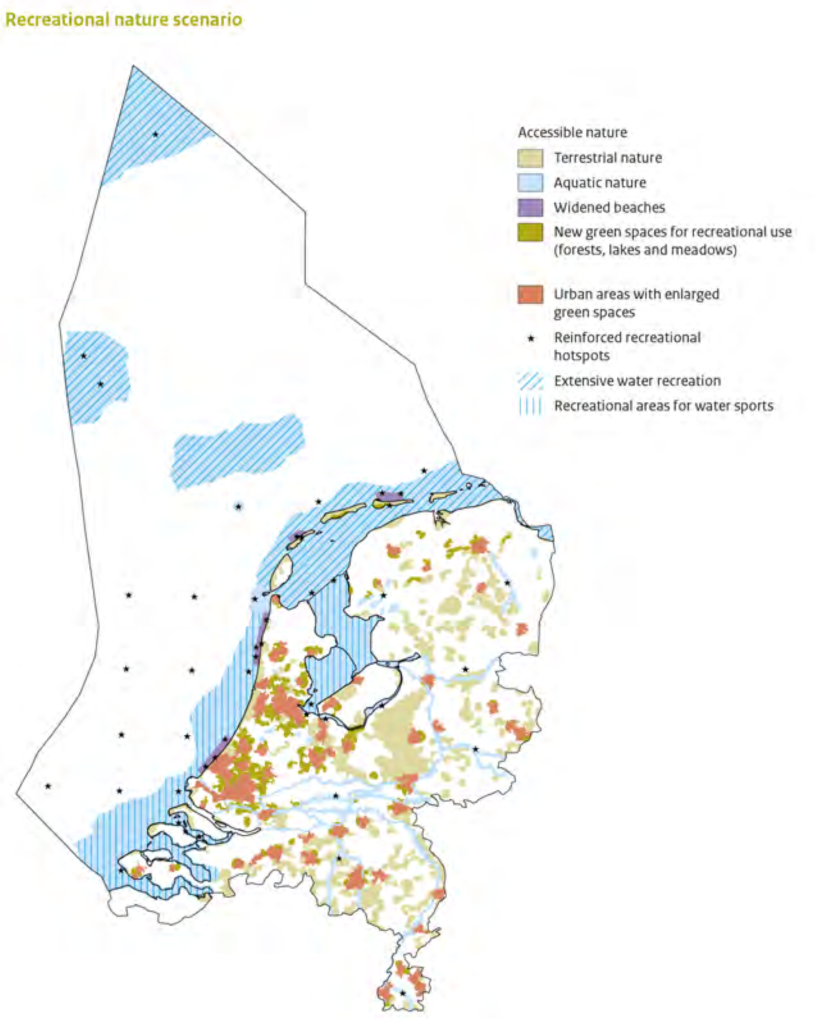

Figure 4.2 Map of Recreational nature (source PBL).

3. Functional nature

From the idea that humans have always made use of natural resources and will always continue to do so, it is important to have a sustainable approach to the use of the North Sea. Man is partly dependent on the resources of the sea, from fisheries and seaweed as food to energy production through water and wind. Sustainable use of the natural resources prevents the depletion of the resources of the North Sea. The natural limit of the resource must be respected. The sea can be used for the production of certain species, such as through aquaculture and mussel culture. The natural deposition of sediment, without human intervention, creates beaches, dunes and salt marshes. Human activities offer opportunities that can benefit nature, such as wind farms as substitutes for hard substrates. Both deep and shallow areas provide breeding grounds for fish. Ecotourism has a number of possibilities. This scenario is most similar to the philosophy of the MSFD.

Considerations:

- Nature can benefit through consideration in the human use of the North Sea: functional combinations such as wind turbines and growing seaweed or wind farms as nurseries for fish, coastal defences and wildlife areas, sand deposition with recreation, ecologically rich seawalls at ports and harbours through the presence of hard substrates.
- System-scale approach and 'gardening at sea' are important. The conditions arising from fishery can be developed for fish stocks, catches and conservation of the seabed. Innovative fisheries.
- Non-indigenous species introduced into the North Sea can be used.

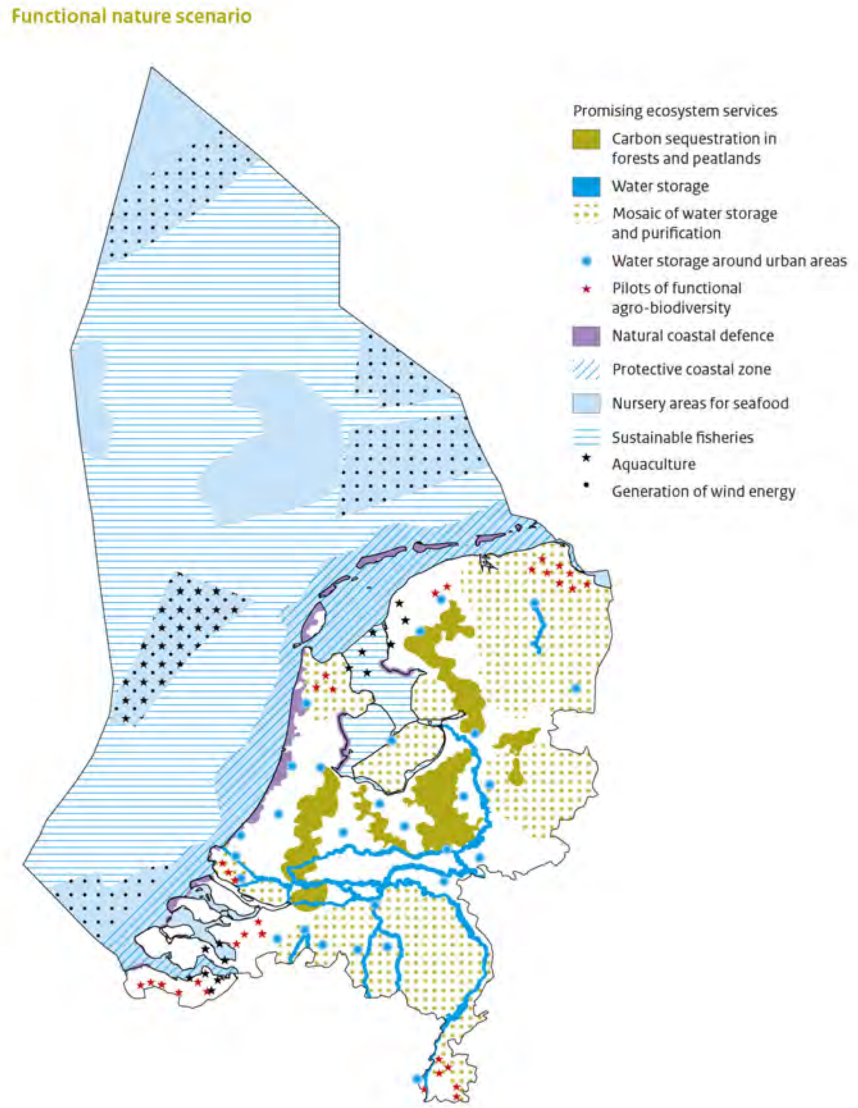

Figure 4.3: Map of functional nature (source: PBL)

4. Flexible nature

From the idea that nature is not fragile, but dynamic and can adapt to changing circumstances as those found in the North Sea. The fish stocks in the southern North Sea are actively managed from a business prospect. Optimal use is made of the coast through ports and havens, intensive recreation and housing (on reclaimed or created land). At various locations along the coast, power can be generated through tidal barrages, osmosis and wind farms that can be developed on a large-scale. As far as is possible costs to nature and wildlife regulations must be limited. Nature is secondary to other uses; it can fit in between gas platforms and wind farms where fisheries are less economically viable. Protecting natural areas is not necessary even in coastal areas, where human use has priority.

Considerations:

- Sand replenishment and sand extraction are desirable.
- Sea and coast as a backdrop for beautiful living.
- Static view on the fishery limits; the fishery reacts to changes in fish stocks and to market factors.
- Development of durable energy and CO_2 reduction at sea relieves pressure on land.
- Land reclamation and new islands fit into this scenario, such as for residential areas, industry, recreation, fossil fuel extraction etc..
- Parts of the North Sea are privately owned or leased.

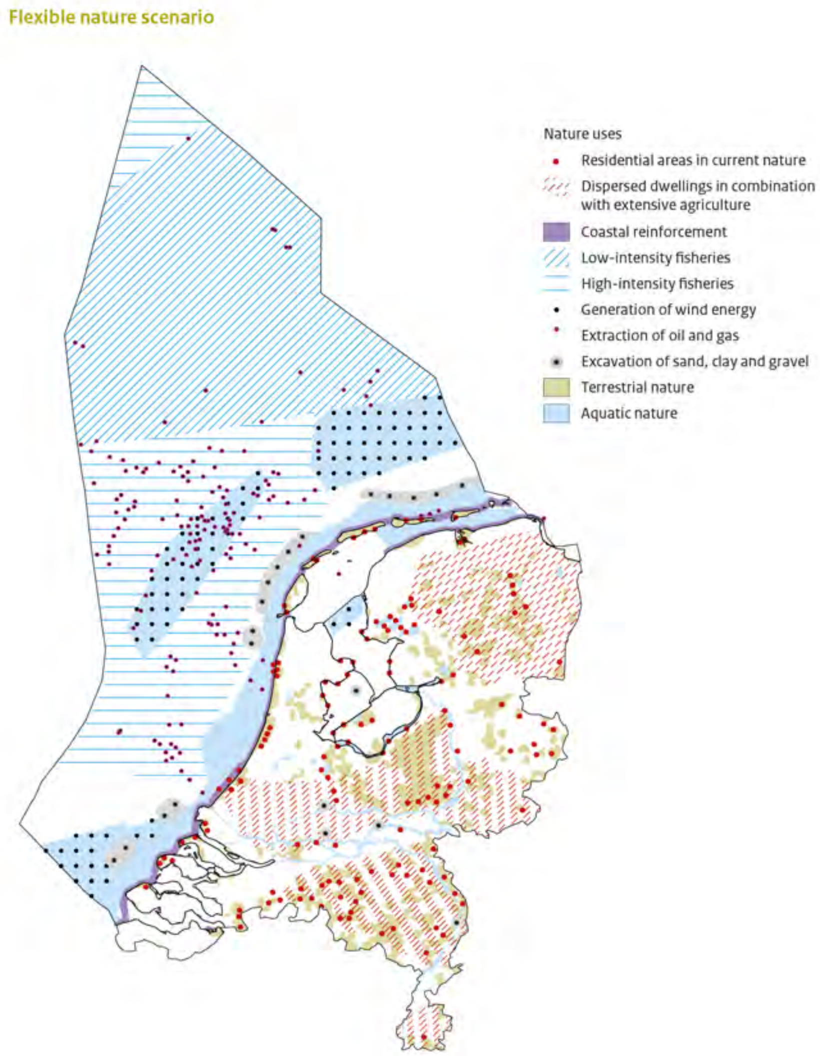

Figure 4.4: Map of flexible nature (source: PBL).

4.2 Eco-points, MSFD descriptors and Nature Outlook scenarios

4.2.1 Linking MSFD descriptors to scenarios

The most important aspects of the scenarios of the Nature Outlook are scored against their impact on the targets of the MSFD descriptors. A preliminary analysis (see table 4.1) shows that the scenarios are relevant to some MSFD descriptors but not all. The descriptor Biodiversity (GES 1) shows most links to the defined key factors. The descriptors Litter (GES 10), Noise (GES 11) and Eutrophication (GES 5) show very few matches with any of the key factors of the scenarios. However, this is a preliminary analysis as secundary effects are not included.

The effects on targets for the MSFD descriptors are not conclusive for much of the scenario's main aspects. This is caused by possible ambiguous effects of certain measures, e.g. fisheries: no bottom trawling will have beneficial impact on bottom biodiversity, but if bottom trawling is replaced by more intensive pelagic trawling, then the effect of no bottom trawling on biodiversity as a whole is uncertain. The spatial aspect is also important as banning fisheries from the coastal zone may increase fishing in other areas. None of the scenarios is explicit in the trade-offs of certain spatial measures on other sectors or on areas elsewhere. However, the Eco-point methodology does explicitly include trade-offs in other sectors and other areas. This means that the detail of the scenario descriptions do not match the detail that is needed for applying the Eco-points method.

Since a scenario represents a separate set of values, individual targets of one scenario may or may not overlap with other scenario's targets. In evaluating scenarios, targets for other scenarios may be evaluated also. This will show whether or not scenarios are compatible for certain aspects. For example: from table 4.1 it can be concluded that recreational value, the driving force behind the Recreational nature scenario, is impaired by the wind farms along the coast as proposed in the Flexible Nature scenario.

The driving forces of the scenarios (in bold in table 4.1), except for the Vital nature scenario, cannot be linked to the MSFD descriptors, i.e. these driving forces tackle aspects that are outside the scope of the MSFD. For example profitability of activities at sea is not a part of the aim of the MSFD, although it is the main driving force in the Flexible nature scenario. The overarching European Maritime Policy does include such aspects however. A complete coverage of these different societal value systems within the (more limited) MSFD is therefore not possible.

Table 4.1. Indicative score chart for important aspects of scenarios on targets for MSFD descriptors. Key aspects in bold are driving forces per scenario.

Viewpoint	Key aspects	Descriptor										
		Biodiversity	Non indigenous species	Commercial Fish	Food web	Eutrophication	Bottom integrity	Hydrographical	Chemical Substances	Chemical Substances in food	Litter	Noise
Vital	**Nature first**	+										
	Biodiversity value											
	Natural processes	+	+	+/-			+					
	Estuaries	+		+/-	+							
	Natural zones	+		+/-	+							
	Complete ecosystem with large predators	+		+/-	+							
	More big fish	+		+/-	+							
	High base biodiversity quality for all of the North Sea	+		+/-	+							
	Unhindered migration along the coast	+		+/-								
	No sand dredging or suppletion	+		+/-								
Recreational	**Enjoyable / astonishing**											
	Recreational value	+/-	-								+	
	Sites for diving and whale watching	+			+		+					
	Less fishery in coastal zone	+/-		+/-	+/-		+/-					
	No visible objects in coastal zone	+/-										
Functional	**Sustainable use**											
	Usage value			+						+		
	No bottom trawling	+/-		+/-			+					
	Protected coastal zone (no fishery)	+		+	+		+					
	Aquaculture	-	-	+/-	-	+/-	+/-					-
	Wind energy	+/-					+					-
	Usage of exotic species	+/-	+									
Flexible	**Economy first**											
	Profitability											
	More shipping		-									-
	More sand dredging	-					-					-
	Wind farms in coastal zone	+/-			+/-		+					-
	More CO2 storage											-
	New islands in the sea	-										-
	Fishery region in SW North Sea	+/-		+/-	-		-					-

4.2.2 Options for adapting the Eco-points method for the evaluation of scenario outcomes in relation to societal value systems

As the Eco-points method was designed to evaluate the effects on biodiversity aspects in the first place, it will perform well when evaluating the Vital nature scenario (main target: enhancing biodiversity). The other scenarios' main targets are only partially (if at all) evaluated by biodiversity apects and the Eco-points method (see above). We propose 3 options for adapting the method to service the societal value systems more closely:

1. Redefine the weighting factor;
2. Define zones of interest;
3. Construct a new method.

1. Redefine the weighting factor

The principles of scenarios can be translated to different values for the weighting factors. This implies that certain aspects of biodiversity or certain indicators of the MSFD are given precedence over others because they are more appealing within the context of a certain societal value system. For example, marine mammals may be given a high weighting factor within the Recreational nature scenario because of their popularity and attractiveness to people. MSFD indicators that describe or imply a great diversity and healthy populations of marine mammals will get high weighting factors for the Recreational nature scenario.

2. Define zones of interest

By defining zones of interest for each scenario, a spatial weighting is introduced. This is an extension of the spatial extent of measures as part of the scenario maps (figures 4.1 to 4.4). For example, the coastal zone is a zone of special interest in the scenario Recreational nature as 90% of recreational activities take place in this zone alone. Indicators that describe or imply recreational attractiveness of the coastal zone will receive high weighting factors in the Recreational nature scenario. The effectiveness of measures within the context of this scenario will be evaluated within the coastal zone only. In the Vital nature scenario, Natura 2000 areas may be viewed as areas of special interest, whereas in the Functional Nature scenario the focus may lay upon good fishing grounds. Another way to implement this option is to apply a weighting factor for different zones for each scenario.

3. Construct a new method

When constructing a new methodology for the evaluation of effects within the context of the Nature Outlook scenarios, new indicators must be defined that specifically apply to the principles of the different societal value systems. The method could still be defined in terms of quality, quantity and weighting factor, analogous to the Eco-point method. The key factors for each scenario (see table 4.1) is the quality factor in the new approach. The quantity factor (surface area) is defined by the spatial extent of the zone of interest (see 2 above). The weighting factor may be quantified by a prioritisation of the key factors for each scenario.

4.3 Discussion

Assessment of how measures planned for the MSFD are valued in the context of the different scenarios requires translation of the key aspects of the scenarios into indicators and quantification of these scenario-specific indicators. This requires additional research. The precise definition of the indicators determines whether they will score positively of negatively for certain MSFD descriptors. A first attempt is presented in table 4.1.

Only certain aspects of the scenario outcomes can be evaluated by the Eco-point method directly. The key aspects of the scenario Vital nature relate all to the MSFD descriptor Biodiversity, but also Food web and Bottom integrity. For the scenarios Recreational nature and Functional nature, certain aspects are coverd by MSFD descriptors, e.g. presence of marine mammals and sustainable fisheries, respectively. Aspects that are not directly or not at all related tot biodiversity need another method to calculate their effects. For profitability, no additional method is needed as costs and profits form the main part of CBA’s. To include the potentially broad scope of the scenarios Recreational nature and Sustainable nature, the Eco-point method could be adapted or a new method could be developed. However, care should be taken that such a method does not introduce overlap (doubling) of values that are already included in the monetized part of the CBA.

The overall requirement for all of the approaches discussed, are the availability of quantitative data, well-defined weighting factors and reliable effect estimation of measures. Some potential parameters may be quantified directly; such as the numbers of tourists making use of the coastal zone can be used to assess the scenario Recreational nature. Other potential parameters may be derived indirectly from the interpretation of ecological data, for example the abundance of birds or large mammals in the coastal zone. Not all potential indicators are easily translated to a quantitative level.

The most feasible option to include the different societal value systems in the evaluation of the effects of MSFD measures, is to explicitly refer to these different value systems in a CBA and present the results of measures for each of the scenarios, according to their specific weighting factors and/or zones of interest. In this approach the effects of measures are expressed directly in the key factors that constitute the societal value systems and not via biodiversity metrics (and not by the Eco-point method as it is defined at the moment).

5 Discussion and conclusions

5.1 Discussion and recommendations

In this study we developed an Eco-point framework for the North Sea and explored the applicability for assessment of MSFD measures. The method proved suitable for this purpose, but for several components future improvements are desirable in order to increase the confidence level, robustness and interpretability of the output. In this section we discuss different aspects of the main components of this study: framework development, suitability for the MSFD and its descriptors and the possibility for assessment of MSFD measures. For each component options for further improvement of the method are suggested.

5.1.1 Framework development

The current method evaluates effects on biodiversity. Recreational values, landscape values, societal appreciation and functional values of nature are not incorporated in the method. We suggest the use of some approaches that link Eco-points to societal scenario's (§4.2.2). However, societal values are also covered by the MKBA in which Eco-points are implemented.

Quantity

Note that the total surface area of the DCS largely exceeds total surface area of the terrestrial surface area of the Netherlands. The total area of the North Sea studied in the Eco-point framework is 59175 km^2. However some measures may affect smaller area's. A measure like “Introducing hard substrate to the seafloor” will never cover a surface area larger than several square kilometres, corresponding to only a small area of the total DCS. Other measures, such as litter reduction, cover the entire North Sea. The large surface area of the study site influences Eco-point output and stresses the importance of an accurate estimation of the effects of measures: a small difference quality, can result in a large difference in Eco-points due to the large size of the impact area. On the other hand: the effect of a measure with a restricted local impact, but a large improvement in quality, will only result in a small difference in Eco-points. Expressing the benefit of measures as a difference in Eco-points (Δ Eco-points) only partly neutralises this effect. Differences in eco-points can be traced to the underlying changes in species groups and individual species as well as to specific areas where these changes occur.

Quality

Data availability

The core of the method relies on the best available data and expert knowledge. We recommend to invest in improving of data-availability for future projects. In this respect a link with the ongoing processes of MSFD and OSPAR indicators and monitoring-programmes is probably efficient.

The quality and properties of the underlying data influences the outcome of Eco-point calculations. For example, rescaled data generate indirect and different quality estimates than continuous data (§2.8.2). Furthermore, the number and type of indicators, as well as the possibility to assess impacts of measures on these indicators, influence the outcome.

Some metrics consist of a complex value, containing several underlying metrics and weighting factors (i.e. 'bird value'). Predicting the (quality) impact of measures on these indicators is more difficult, then for a simple metric like 'density' or 'species diversity'. Furthermore, in this study 'bird value' is used as the only metric for a species group, and therefore a reliable impact-estimation is even more important. A higher number of easily interpretable metrics per species group may improve the results.

Selection of metrics

The current set of metrics is mainly based on data availability. For spatial differentiated data, this study relied upon the data that were gathered and presented in the study by Bos *et al.* (2011). These metrics are specifically designed to compare different locations within the North Sea. However, their suitability as a metric for assessing effects of MSFD measures is limited. Metrics that are aggregated to a high level (such as the bird values) make it impossible to link specific measures to individual species (e.g. on the basis of food source) and thus to assess the impact on overall bird biodiversity. Bird data were aggregated to a single map/parameter ("bird value"), which encompasses underlying metrics, but does not allow the use of multiple metrics for this group. Marine mammal metrics were based on weighted single species values that originated from expert judgement. Weighting, however, is based on a weighting factor 1 to 5 that is assigned to each of 5 mammal species. This weighting factor is classed according to the relative position of each of 5 mammal species. This means that if the rarity value of one species decreases, it automatically increases for another species. This interrelation causes problems for absolute quality estimations and even more in predicting measure effect size.

Metrics should be checked against their responsiveness to changes in habitat characteristics. If there is no scientific data (or expert knowledge) to support the response of individual metrics, then the inclusion of these metrics should be reconsidered especially when using them for estimating the effect of measures. Maintaining these non-sensitive metrics in the method, introduces bias and may underestimate the effects of measures. When the aggregated metric is used to estimate the effects of measures (e.g. setting the quality for macrobenthos to 100% in the case of the introduction of hard substrate) then the individual detailed metrics (e.g. density, biomass, rarity, large species and species richness) are redundant.

In the MSDF process, indicators for the GES are being developed and evaluated. It would be useful, in optimisation of the Eco-points metrics, to consider the final set of indicators and metrics for GES descriptor 1 in the context of the Eco-point framework. Ideally, in order to improve comparability and inpertrability, the the same set of metrics should be used within the Eco-point framework.
In a search for new metrics for biodiversity we recommend to stay close to the development of GES 1 indicators and metrics, and additionally to those of GES 2 (Exotic species), GES 4 (Food webs) and GES 5 (Eutrophication) and GES 6 (Sea bottom integrity) where applicable and dependent on the further definition of the specific indicators. As a parallel to the WFD, metrics that specify characteristic species of communities per habitat, would make a useful amendement.

Maximum quality
The current state of quality metrics is used as the baseline (or reference) from where effects of measures are calculated. In this study the maximum obtainable quality of a habitat has been defined as the maximum quality that has been observed per metric within the habitat type. This approach implies that measures cannot lead to improvement beyond the current maximum quality level. The currently used maximum quality values strongly depend on the input-data and the range of values within each habitat. Thus, parts of the DCS that have been assigned current maximum quality levels in this study, can not be improved beyond this maximum level by specific measures directed to improve biodiversity, although in reality improvement might be possible or even probable. This will result in underestimating the effects of those measures that have a larger quality impact. Although the usage of current quality levels as maximum quality levels seems in accordance with current Dutch policy ambitions (no deterioration) (Prins *et al.* 2011), for technical purposes this approach is less suitable, as improvements in specific aspects of the ecosystem may be obscured. Therefore it would be more opportune to include in the future a natural reference in the Eco-point method. This reference situation can be based on both data and expert judgement, comparable to the methodology applied in the Water Framework Directive.

Weighting factor
We explored three ways of developing an appropriate weighting factor:

1) Habitat rarity
Habitat rarity was calculated as a weighting factor, based on the available surface area of habitats for the DCS. The basic assumption was that a unit of a rare habitat contributes more to total biodiversity than a common habitat. However this assumption is not based on true biodiversity values. When considering habitat-wide measures, the difference in total surface area (quantity) is compensated by the weighting factor. Thus, habitat-wide measures in different habitats of different size, do not generate different Eco-point totals, except when the quality of these habitats differs. However, measures that only cover parts of habitats will generate different Eco-point totals (see § 3.3).

2) Habitat fidelity

The use of fidelity of species to specific habitats as a weighting factor is in line with the weighting factor used in previous CBA studies using Eco-points or related nature indicator systems (Sijtsma *et al.* 2009). Furthermore this approach is more likely to weight habitats based on their importance for the biodiversity of the North sea.

Due to lack of data the weighting factor in this study was solely based on macrobenthos. Macrobenthos is a suitable indicator for local habitat quality as it is relatively loyal to a specific type or quality of substrate (Lindeboom *et al*. 2008). Sijtsma *et al.* (2009) propose a more complex weighting factor, including total number of species in addition to habitat fidelity. They also indicate that weighting habitat fidelity increases differentiation between habitat types, which is useful in the North Sea Eco-point framework, consisting only of eleven habitat types, which is rather rough compared to terrestrial and aquatic nature target types (Bal *et al.* 2001). Furthermore species richness of macrobenthos is high and detailed sampling data were available, although not all habitats were covered.

In this study the Cleaverbank macrobenthos samples were treated as one location, whereas in fact they belong to 100 sub-locations in two different habitats (see figure 2.5). This can be solved in future framework development. Also the number of locations and samples per habitat differ strongly, resulting in an unbalanced species selection per habitat. Since numerous species show low densities, their presences in a habitat is strongly based on sampling effort. This must be kept in mind when using this weighting factor. Adding more data and species groups, the use of a balanced and complete data set and a differentiation based on functions of habitats or densities of species improves the robustness of this weighting factor for future applications.

A side note for the future use of habitat fidelity, originates from the ecology of marine species. When calculating habitat fidelity using existing databases, species obtain higher values if they are found in one habitat and not in others. Most marine species, however, show pelagic dispersal at some stage of their life (mostly larval). Specimens that randomly end-up in an unsuited habitat may live there, but generally no viable population is established. For example, a common hard-substrate specialist fish such as the rock gunnel (*Pholis gunnellus*), generally lives in hard substrate habitats and is dependent on deep crevices and holes for its reproduction. This species does, however, have a larval pelagic phase of some weeks and individuals may end up on sandy bottoms far from any hard substrate. As a result there presumably is no habitat on the DCS where this species hasn't been caught in a beam trawl survey, so this species will not be identified as 'unique for hard substrates' when searching databases and habitat fidelity will be low. Yet it's existence depends on the presence of the rare hard substrate habitats.

3) Scenarios

Translating key factors of societal value systems to a weighting factor in the Eco-point framework proved not to be satisfactory. Main bottleneck for this approach is the lack of quantifiable data, and reliable impact assessment of measures on scenario factors. Nevertheless, some feasible options exist to implement scenarios in an Eco-point framework or a CBA (see chapter 4).

For future consideration:

1. A reliable weighting factor can only be calculated from reliable monitoring data. For some combinations of habitats and species groups these data are not available at the moment. Special attention is needed for rare species whose recorded presence may be directly related to sampling effort.
2. Species may occur in a wide range of habitats as they are transported by currents in one or all life stages. This doesn't mean that these species are distributed evenly over habitats in terms of biomass or numbers, or that their presence in a habitat always has an ecological background. Certain habitats may play an essential role in certain life stages for species though. Scoring the presence or absence of species does not reflect this completely. Scaling according to biomass might lead to improvement of the weighting factor for marine habitats.
3. Species may depend on specific habitats for specific functions, such as reproduction areas for fish. These more or less delineated areas may or may not correspond to a specific habitat and may be determined by other factors that are not included in the habitat classification or that may even change from year to year (e.g. seawater temperature). In this way a habitat may be essential for a number of species (and thus for biodiversity) whereas these species occur in other habitats in other stages of their lives, thereby not adding to the importance (and weighting factor) of their key habitat. It would be even more sophisticated to include functional aspects of habitat types in the weighting factor.

5.1.2 Suitability to MSFD

The quality metrics in the Eco-point method fit to the MSFD indicators. However due to lack of data not all indicators and metrics could be used. Since effects of measures have to be calculated, data availability and expert knowledge of the sensitivity of indicators and metrics should be a dominant selection criterion. The developing process of MSFD metrics and indicators used to measure progress towards the GES, will meet this same problem of data availability. Adapting monitoring programmes may solve the problem in the future, but is no solution for the current application of the Eco-point method. Nevertheless, we consider this not as a critical element for the current application, since the selected metrics give a broad view on North Sea biodiversity, which is sufficient for a prioritisation of measures.

The method is suitable for comparing different options or scenarios of measures. Standalone, the value and accuracy of the outcomes are not meaningful. Other studies focus on more complete biodiversity indicators (i.e. Boon *et al.* 2011, Bos *et al.* 2011). The outcome is not meant to measure progress towards the GES. For an outcome that corresponds closely to GES objectives, we recommend to include final

MSFD quality indicators as soon as these have been defined at the (inter)national level.

5.1.3 Implementation for other GES-descriptors

Initially the Eco-point framework has been developed for quantification of effects on biodiversity in scenario analyses. In the presented case studies of MSFD measures, the measure ‘sea floor restoration’ solely affects indicators for GES 1. However, in the future, other measures may come in view that relate to pressures that affect other GES indicators.

GES 2, ‘Non indigenous species’ (NIS), is not directly affected by the measure ‘sea floor restoration’. So far, measures that relate to GES 2 are included in international agreements and obligations (e.g. IMO) and not in the MSFD. Therefore it is discussed in international MSFD–context whether this descriptor should be considered during the development of management measures (Löffler *et al. in prep*).

Application of the Eco-point method for assessment of measures for GES 2 is expected to be technically feasible when indicators and targets are defined and data are available. For application in the Eco-point method targets have to be scaled, based on the actual situation and target levels. When spatial data of indicators (or underlying metrics) are available, and related measures are (also spatially) defined, Eco-points can be calculated for these indicators. A bottleneck similar to the one in this study, is that effects of measures, such as active elimination of newly introduced species in yacht harbours and mandatory regular cleaning of sea chests (see appendix 4), are difficult to predict. The proposed MSFD-measures are implemented on specific locations (such as harbours), aiming a reduction of the risk of introduction through pathways and vectors. The translation to spatial distribution and numbers of NIS is not being modelled yet and will be extremely difficult to assess.

For GES 4, ‘Food webs’, an effect of the measure ‘sea floor restoration’ may be expected. The indicators focus on key species and trophic groups at the top of food webs like key predator species and large fish. So far, for the Dutch situation this has been translated in using the EcoQO for harbour seals, bycatch of harbour porpoise and proportion of large fish (Boon *et al.* 2011). For seals extensive knowledge is available for numbers on land. However, a gap in knowledge is behaviour and distribution patterns of seals at sea (Löffler *et al. in prep*.). Spatial data on the distribution of large fish are available, although the data contain blanks (Bos *et al.* 2011). A problem for this indicator is how to estimate effects of measures, taking into account autonomic trends, for example as a result of climatic change. The indicator is sensitive for measures that concern fisheries. The relationship between sea floor restoration measures and numbers of harbour porpoises as bycatch is indirect and therefore difficult to establish. An approximate estimation through expert judgement combined with fish data might be sufficient. Nevertheless GES 4 remains a complex descriptor, that still needs national and international elaboration (Löffler *et al. in prep.).*

Descriptor GES 6, aims that 'sea-floor integrity' is at a level that ensures that the structure and functions of the ecosystems are safeguarded and benthic ecosystems, in particular, are not adversely affected. The proposed MSFD-measure (introducing hard substrate items in bottom-protection zones), indirectly affects this descriptor, as it closes an area for fishing activities. Targets are an increase in the abundance and extent of biogenic substrate, a decrease in the proportion of the seabed that is disturbed by human activities and an increase of long-lived species and macrobenthos above some specified length/size. Boon *et al.* (2011) are of the opinion that a quantitative relation between physical disturbance and the indicators and targets mentioned above is not well established, and therefore only directional targets can be set at present. The Eco-point framework is a suitable tool for incorporating estimations of effects of measures on indicators of descriptor 6, however at this moment the lack of knowledge does not allow a prediction of the effects of measures on specific indicators. A compromise may be found in taking into account only the area of a disturbed versus an undisturbed seafloor, an undisturbed sea floor corresponding to a higher level of sea floor integrity.

5.1.4 Case study MSFD measures

Application of the method using MSFD measures must be considered as an indicative exploration in this study. First, the number of MSFD-measures we tested was limited and measures were not sufficiently specific to enable proper estimation of ecological effects. Therefore we used self-defined specifications of the measure (§3.4.1). The outcome may therefore not correspond to the effect of the definite MSFD measure. Secondly, an assessment of the ecological effects of these measures was not available (Reinhard *et al.* 2011). We therefore estimated the effects through expert judgement. For a reliable prediction of the effects of MSFD measures, conditions should be specified and a more elaborate consultation and reference study would be desirable.

The effects of measures per species group are calculated through a mean habitat specific local quality increase across all metrics. So if the quality score only one out of four metrics increases by 20%, the average gain for that species group is 5%. The quality score thus increases by 5% as a result of the measure. This results in a well balanced impact assessment, that corresponds closely tot the expected impact on the GES descriptor biodiversity, which is also a composed indicator.

Some measures may change the habitat type. For example when large amounts of hard substratum are introduced to a sandy habitat type. To define if a measure will result in change of habitat type, the current definitions of habitat types are helpful (Bos *et al*. 2011). For the habitat type gravel a surface area of 50% gravel is defined as the bottom line. So, sandy substratum containing a surface area of 49 % of gravel is considered as sandy habitat. It is plausible that certain measures in the future may trigger the definition of new habitat types, or that solitaire hard substratum elements are mapped and assessed separately. In the present case study the addition of hard substrate elements lead to an increase in quality of sandy substrate, through an increase of micro-habitat diversity within the habitat type.

As we referred maximum quality to the current maximum quality

5.1.5 Uncertainty analysis

It is difficult tot set a minimum number of Eco-points that should be reached in order to justify a significant difference in biodiversity output of two different options or measures. This is partly due to the fact that several steps in the methods cause an amount of variation or uncertainty in the outcome, and make it difficult to compare to a true state. An approach for an uncertainty analysis would be to consider the uncertainty of the different input values. We prioritised these aspects as:

1. definition and calculation of the weighting factor;
2. data availability (treatment of blanks, aggregation methods, continuous data);
3. definition of maximum quality;
4. estimation of the ecological effect of measures;
5. estimation of the area affected by measures.
6. effect of number of metrics (incl. effect of not-affected metrics)

These aspects have to be addressed in future analyses and improvement of the methodology to improve its reliability for application in a CBA.

5.1.6 Future development

Metrics and weighting factors, as well as the impact assessment are suitable for use in SCBA, but can be optimized to improve the confidence and interpretability of the output. This development should be towards the use of simple metrics, multiple metrics per species group and basic data. A second option for potential improvement is further elaboration of the weighting factor, preferably including all species groups and all habitats. Thirdly impact assessment of measures should be elaborated for all MSFD measures and harmonised by a number of experts. Finally to weight the output of the method in the process of decision making, the definition of a treshold value based on a uncertainty analysis would be helpful.

5.2 Conclusion

In this study the Eco-point methodology has been explored as a tool to assess and quantify effects on biodiversity of MSFD measures. The Eco-point method appears promising, as the intrinsic value of nature can be expressed in a single, clear and similar manner, and ranking of different options is enabled. However the absolute numbers have no stand-alone value. In this way the Eco-point North Sea framework explicitly aims at quantifying effects of MSFD on biodiversity in a uniform way that is more useful than just comparing plusses and minuses.

The Eco-point North Sea framework has been developed, calibrated and tested for MSFD-measures. Two case studies, in which different MSFD measures are tested, show that the method results in different Eco-point totals for different measure designs. The methodology is flexible, transparent and communicable, and is therefore a helpful tool for decision-making or optimisation of location, size and type of restoration measures for the North Sea.

The current methodology is suitable for measures with established impacts on biodiversity. The predicted impact on biodiversity of measures is a strong determinant for the outcome in Eco-points, thus uncertainties in impact assessment result in large uncertainties in Eco-points. The properties of data used as input for the study influence the calculation of effects of measures as well. Finally the outcomes in Eco-points are strongly affected by the selected biodiversity metrics, weighting factors and reference values used.

Calculated Eco-point-totals are meaningful in comparing different measures or scenarios, based on the same parameters and data selected for the Eco-point method. The absolute numbers that are generated can be weighted in a CBA.

Key aspects of societal value systems proved difficult to incorporate in the Eco-points method at this stage. However, the inclusion of these different value systems in future CBA's of the MSFD seems a useful option.

We estimate that the presented Eco-point method for the North Sea is essentially suitable for assessment of other measures, generated by other policies or future developments. However, since the outcomes of the Eco-point calculations are strongly affected by the selected biodiversity metrics, weighting factors and impact assessment of MSFD measures, future steps should include an in-depth study and adjustment of these factors. Some suggestions for improvement are discussed.

6 Literature

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Appendices

Appendix 1: GES Descriptors and indicators

Overview of criteria and indicators (EC, 2010) and proposed indicators. S indicates status: red: no indicator; orange: indicator needs some elaboration; green: existing indicator; hatching: indicator partly covers EC (2010). (from: Boon et. al. 2011)

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
1. Biological diversity			
Species distribution (1.1) *Distributional range (1.1.1)*	orange	Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived/vulnerable species in benthic community Fish: • number of species with a long-term negative trend • Threat indicator Birds: • Vulnerable species Marine mammals: • Number of grey seal, harbour seal, harbour porpoise	Increase in number/biomass Increase in proportion Zero Reduction in the rate of increase No decline No decline
Species distribution (1.1) *Distributional pattern within the latter, where appropriate (1.1.2)*	orange		
Species distribution (1.1) *Area covered by the species (for sessile/benthic species) (1.1.3)*	orange		
Population size (1.2) *Population abundance and/or biomass, as appropriate (1.2.1)*	orange		
Population condition (1.3) *Population demographic characteristics (e.g. body size or age class structure, sex ratio, fecundity rates, survival/mortality rates) (1.3.1)*	green	Fish: • OSPAR EcoQO proportion of large fish in the fish community • Size diversity index Marine mammals: • OSPAR EcoQO on healthy seal populations	More than 30% of fish should be longer than 40 cm in the IBTS Increase towards a value of 1 No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean
Population condition (1.3) *Population genetic structure, where appropriate (1.3.2).*	red	Not applicable yet	
Habitat distribution (1.4) *Distributional range (1.4.1)*	orange	Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Habitat distribution (1.4) *Distributional pattern (1.4.2)*	orange		
Habitat extent (1.5) *Habitat area (1.5.1)*	orange		
Habitat extent (1.5) *Habitat volume, where relevant (1.5.2)*	orange		
Habitat condition (1.6) *Condition of the typical species and communities (1.6.1)*	orange	Benthos: • number/biomass of long-lived/vulnerable species • proportion of long-lived /vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Habitat condition (1.6) *Relative abundance and/or biomass, as appropriate (1.6.2)*	orange		
Habitat condition (1.6) *Physical, hydrological and chemical conditions (1.6.3)*	orange	Distribution and pattern of habitats at EUNIS level 3	No decline in distributional range
Ecosystem structure (1.7) *Composition and relative proportions of ecosystem components (habitats and species) (1.7.1)*	orange	Benthos, Fish: • Species richness • Species evenness, Hill's N_1, Hill's N_2 Birds: • Bird values Marine mammals: • Species richness	No decline Values do not exceed the range typical for the monitoring site Values do not exceed the range typical for the monitoring site No decline

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
2. Non-indigenous species			
Trends in abundance, temporal occurrence and spatial distribution in the wild of non-indigenous species, particularly invasive non indigenous species, notably in risk areas, in relation to the main vectors and pathways of spreading of such species (2.1.1)		Number of non-indigenous species Abundance of non-indigenous species	No increase No increase
Ratio between invasive non-indigenous species and native species in some well studied taxonomic groups (e.g. fish, macroalgae, molluscs) that may provide a measure of change in species composition (e.g. further to the displacement of native species) (2.2.1)		Ratio of non-indigenous:native species in a selection of groups (phytoplankton, benthos, fish)	No increase
Impacts of non-indigenous invasive species at the level of species, habitats and ecosystem, where feasible (2.2.2)		To be determined dependent on species, habitat and ecosystem characteristics	No impact
3. Commercially exploited fish			
Fishing mortality (F) (3.1.1)		Fishing mortality of commercially exploited fish	Below F_{MSY} (ICES advice for values of F_{MSY})
Secondary indicator: Ratio between catch and biomass index (hereinafter catch/biomass ratio) (3.1.2)		Catch/biomass ratio of commercially exploited fish	No increase
Spawning Stock Biomass (SSB) (3.2.1)		SSB of commercially exploited fish	Below SSB_{PA} (ICES advice for values of SSB_{PA})
Secondary indicator: Biomass indices (3.2.2)		Log-transformed abundance of commercially exploited fish	No decline
Proportion of fish larger than the mean size of first sexual maturation (3.3.1)		Proportion of fish larger than the mean size of first sexual maturation	No decrease
Mean maximum length across all species found in research vessel surveys (3.3.2)		Not applicable	
95% percentile of the fish length distribution observed in research vessel surveys (3.3.3)		95% percentile of the fish length distribution observed in research vessel surveys	No decrease
Secondary indicator: Size at first sexual maturation, which may reflect the extent of undesirable genetic effects of exploitation (3.3.4)		Size at first sexual maturation	No decrease
4. Food webs			
Performance of key predator species using their production per unit biomass (productivity) (4.1.1)		OSPAR EcoQO on healthy seal populations Abundance of prey species of grey seal and harbour seal	No decline of >10% in grey seal pup populations or harbour seal populations over a five-year running mean No decrease
Large fish (by weight) (4.2.1)		OSPAR EcoQO proportion of large fish in the fish community	More than 30% of fish should be longer than 40 cm in the IBTS survey Increase in average size (by weight) of pelagic fish
Abundance trends of functionally important selected groups/species (4.3.1)		OSPAR EcoQO on by-catch levels of harbour porpoise	Below 1% of best population estimate
5. Eutrophication			
Nutrients concentration in the water column (5.1.1)		Winter means of dissolved inorganic nitrogen	DIN (µM) = 184,7-5,057*salinity for salinities<30 33 for salinities ≥30
Nutrient ratios (silica, nitrogen and phosphorus), where appropriate (5.1.2)		N:P ratio (based on winter means)	Between 10-37.5

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
Chlorophyll concentration in the water column (5.2.1)		90-percentile of growing season concentration	Chl-a (µg/l) = 21 for salinities<30.4 144-4.045*salinity for salinities ≥30.4 and <34.5 4.5 for salinities≥34.5
Water transparency related to increase in suspended algae, where relevant (5.2.2)		Not applicable	
Abundance of opportunistic macroalgae (5.2.3)		Not applicable	
Species shift in floristic composition such as diatom to flagellate ratio, benthic to pelagic shifts, as well as bloom events of nuisance/toxic algal blooms (e.g. cyanobacteria) caused by human activities (5.2.4)		Frequency of blooms of *Phaeocystis globosa*	≤2 months per year
Abundance of perennial seaweeds and seagrasses (e.g. fucoids, eelgrass and Neptune grass) adversely impacted by decrease in water transparency (5.3.1)		Not applicable	
Dissolved oxygen, i.e. changes due to increased organic matter decomposition and size of the area concerned (5.3.2)		Annual minimum concentration of oxygen	>= 5 mg/l
6. Sea-floor integrity			
Type, abundance, biomass and areal extent of relevant biogenic substrate (6.1.1)		Abundance and areal extent of biogenic substrate	Increase in abundance and areal extent
Extent of the seabed significantly affected by human activities for the different substrate types (6.1.2)		Proportion of surface area of each habitat (EUNIS level 3) affected by human activities in the last year	Decrease
Presence of particularly sensitive and/or tolerant species (6.2.1)		Number/biomass of long-lived/vulnerable benthos species Proportion of long-lived/vulnerable species in benthic community	Increase in number/biomass Increase in proportion
Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species (6.2.2)		BEQI Species richness Species evenness Hill's N_1 Hill's N_2	Values do not exceed the range typical for the monitoring site
Proportion of biomass or number of individuals in the macrobenthos above some specified length/size (6.2.3)		Length-frequency distribution of bivalves	No decrease
Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community (6.2.4)		Not applicable	
7. Hydrographical conditions			
Extent of area affected by permanent alterations (7.1.1)		Total (cumulative) surface area that has permanently changed	*The impact of human activities that permanently change part of a marine area is only to some extent related to the surface area. It is therefore not feasible to set a meaningful target for this indicator*
Spatial extent of habitats affected by the permanent alteration (7.2.1)		Total (cumulative) surface area where permanent changes occur	*See above*
Changes in habitats, in particular the functions provided (e.g. spawning, breeding and feeding areas and migration routes of fish, birds and mammals), due to altered hydrographical conditions (7.2.2)		To be determined dependent on type of activity	

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
8. Contaminants			
Concentration of the contaminants mentioned above, measured in the relevant matrix (such as biota, sediment and water) in a way that ensures comparability with the assessments under Directive 2000/60/EC (8.1.1)		Concentrations of contaminants in water, sediment, suspended matter and/or biota	WFD-Environmental quality standards (EQS) for contaminants in water OSPAR-Environmental assessment criteria (EAC) for contaminants in sediment and biota
Levels of pollution effects on the ecosystem components concerned, having regard to the selected biological processes and taxonomic groups where a cause/effect relationship has been established and needs to be monitored (8.2.1)		OSPAR EcoQO on level of imposex in dogwhelks and other gastropods Various biological effects indicators	The average level of imposex should be consistent with exposure to TBT concentrations below the environmental assessment criterion OSPAR/ICES EAC's
Occurrence, origin (where possible), extent of significant acute pollution events (e.g. slicks from oil and oil products) and their impact on biota physically affected by this pollution (8.2.2)		OSPAR EcoQO on number of oiled guillemots	The average proportion of oiled common guillemots in all winter months (November to April) should be 10% or less of the total found dead or dying, over a period of at least 5 years
9. Contaminants in seafood			
Actual levels of contaminants that have been detected and number of contaminants which have exceeded maximum regulatory levels (9.1.1)		Levels of contaminants in fish and seafood	Regulatory levels from Commission Regulation (EC) No 1881/2006 and the 'Warenwet"
Frequency of regulatory levels being exceeded (9.1.2)		Annual frequency of observations where levels are exceeded	Zero
10. Litter			
Trends in the amount of litter washed ashore and/or deposited on coastlines, including analysis of its composition, spatial distribution and, where possible, source (10.1.1)		The average amount of litter items washed ashore on reference beaches	Decrease
Trends in the amount of litter in the water column (including floating at the surface) and deposited on the sea-floor, including analysis of its composition, spatial distribution and, where possible, source (10.1.2)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	Less than 10% of fulmars with more than 0.1 g of plastic in their stomach, over a period of at least five years
Trends in the amount, distribution and, where possible, composition of micro-particles (in particular micro-plastics) (10.1.3)		Not applicable yet	
Trends in the amount and composition of litter ingested by marine animals (e.g. stomach analysis) (10.2.1)		OSPAR EcoQO on the level of litter (plastic particles) in fulmar stomachs	See above
11. Underwater noise			
Proportion of days and their distribution within a calendar year over areas of a determined surface, as well as their spatial distribution, in which anthropogenic sound sources exceed levels that are likely to entail significant impact on marine animals measured as Sound Exposure Level (in dB re 1μPa2.s) or as peak sound pressure level (in dB re 1μPapeak) at one metre, measured over the frequency band 10 Hz to 10 kHz (11.1.1)		Not developed yet	
Trends in the ambient noise level within the 1/3 octave bands 63 and 125 Hz (centre frequency) (re 1μPa		Not developed yet	

Criteria and indicators (EC, 2010)	S	Proposed indicator	Proposed target
RMS; average noise level in these octave bands over a year) measured by observation stations and/or with the use of models if appropriate (11.2.1)			

Appendix 2: Data

Ideally, in a study for the MSFD, indicators and monitoring data selected and (internationally) approved for the specific purpose, would be used in calculating the effects of measures. However, since both indicators and metrics for the MSFD descriptor biodiversity are still discussed, a short-term, a pragmatic solution was sought to apply the Eco-points method to in this study.

For the development of the Eco-points method for the North Sea, we used metrics and data of the maps as described in "Biodiversity hotspots on the Dutch Continental Shelf" (Bos et al. 2011) as a basis. These were the only readily available spatial data on the biodiversity of the Dutch North Sea at the time. Origin, processing steps and restrictions of these data are described in this report and summarised in table II.1.

Table II.1 Data available through the work of Bos et al. (2011).

Data		**Description**	**Restrictions**
Benthos	Macrobenthos	MWTL/BIOMON 1991-2006	Point data
	Megabenthos	Triple D dredge 2008-2010	Not available
	Macro & Megabenthos	BTS bycatch	Not available
Fish	Demersal fish	BTS(1985-), IBTS(1977-) and DFS (1995-)	
Birds	Seabirds	ESAS and bimonthly aerial counts 1991-2008	Aggregated (Bird value)
Marine mammals		ESAS and bimonthly aerial counts, seal counts	Expert judgment and interrelatedness (weighting)

In Bos *et al*. (2011) biodiversity metrics are developed for the GES descriptor 1 of the MSFD. The selection of metrics is based on the proposed indicators of biodiversity in the EU Commission Decision (EU 2010). Moreover the proposed metrics were defined and selected in the light of spatial protection measures (Annex VI of MSFD). At the same time all available data of the DCS were explored. Available data suitable to quantify these metrics were collected and aggregated in a database. Ultimately, they provided maps with 5 concise classes to define the current status of specific metrics in specific area's in the DCS. This extensive work provides a sound basis for the 'Eco-point North Sea Framework' that is presented here.

Appendix 3: Selection criteria

Criteria to select indicators and metrics for GES disriptors have been summarized in a number of reports on this subject (OSPAR, 2007a, OSPAR COGEM 2011, Boon *et al.* 2011). For the purpose of the Eco-point North Sea framework, indicators should be specifically:

1. Easy to understand and communicate, so that non-scientific audience (e.g. policy decision makers, stakeholders) can translate the indicated value (*Communication)*;
2. Applicable to a large portion of the geographical area it is used in (*Applicability)*;
3. Based on readily available data and information (*Availability)*;
4. Sensitive to changes caused by measures, allowing detection against background variation (low responsiveness to natural changes (*Sensitivity)*.

In general indicators should be:

5. Ecologically relevant and underpinned by a sound theoretical and scientific basis (S*cientifically based);*
6. Primarily responsive to a single and specific change as opposed to a complex of changes at the same time (*Specificity)*:
7. Easily measurable with a low error rate and capable of being updated regularly (*i.e.* existing monitoring programme) (*Measurement/accuracy*).

We imposed these criteria on the available indicators as proposed by Bos *et al*. (2011) as a starting point for the selection of metrics (§2.4.5).

Appendix 4:
Related policies and conventions

OSPAR

The OSPAR-convention emphasises the reduction of various forms of pollution and disturbances on the marine life and biodiversity from both marine and land-based activities. There is a strong relationship between objectives and methods of MSFD and OSPAR. It is especially the aspect of Ecological Quality Indicators that is of interest for the Eco-point methodology.

The OSPAR Inter-sessional Correspondence Group - Biodiversity Assessment and Monitoring (ICG-COBAM) provides a coordinating role in the development of MSFD products related to biodiversity. This includes the definition of GES and related indicators and targets, primarily for GES descriptors 1, 2, 4 and 6. In June 2011, an Advice Manual on biodiversity was produced. In this document approaches are described for determining GES, setting of environmental targets and selecting indicators for MSFD descriptors 1, 2, 4 and 6.

In collaboration with ICES, OSPAR has developed Ecological Quality Objectives (EcoQOs) as tools to apply the ecosystem approach to the management of human activities that may affect the marine environment. EcoQOs function both as indicators (to provide specific issues for monitoring) and objectives (against which to measure progress). Together, they are intended to provide comprehensive coverage of the ecosystem and the pressures acting upon it, so that meeting all EcoQOs should indicate that the ecosystem is in a good state. Where EcoQOs are not met, this indicates the need for appropriate measures to regulate this specific human activity, or triggers further investigations into possible reasons for the EcoQO not being met.

OSPAR has decided the following EcoQOs should be applied in the North Sea:

- Safe fish stocks
- Healthy seal populations
- Minimize bycatch of harbour porpoise
- Limiting the input of oil into the sea
- Decreasing the impact of TBT containing antifouling paints
- Limiting the input of mercury into the marine environment
- Limiting the input of organochlorines into the marine environment
- Diminishing litter in the marine environment
- Restore large fish
- Reduction of eutrophication

OSPAR also works on a number of additional EcoQOs, one of which concerns habitat quality. The OSPAR maritime area comprises many different habitat types. Some 18 threatened and/or declining habitats have been identified in the OSPAR region. In the North Sea these include oyster and mussel beds, eelgrass beds and cold water coral reefs. The extent and quality of some habitats are threatened by human activities such as fishing, land reclamation and the building of littoral structures.

Water Framework Directive

The Water Framework Directive (WFD) primarily targets freshwater systems (lakes and rivers), groundwater systems, transitional waters and coastal waters. Overlap with MSFD exists in coastal waters, meaning surface water within one nautical mile beyond the seaward side from the nearest point of the baseline from which the breadth of territorial waters is measured, extending where appropriate up to the outer limit of transitional waters.

The objective of the WFD is a Good Ecological Status (GES[2]) of all waters by 2015. GES in the WFD consists of Good Chemical Status and Good Ecological Status, being assessed on several parameters, following the 'one out, all out' principle. Chemical quality is measured through 41 substances, for which target values are defined at a European level. For the Dutch part of the North Sea (1-mile zone), target values for chemical substances are presently already met. Ecological quality targets are defined for: hydro-morphological status; general physical-chemical parameters; specific contaminants; and biological groups of species. The ecological quality targets are not expected to be met for all Dutch coastal waters by 2015 (PBL 2008).

For several of the MSFD descriptors (*e.g.* contaminants, eutrophication, hydrographical conditions, sea floor integrity), good environmental status in coastal water bodies will be delivered largely or entirely through the measures to be taken under the WFD. Other descriptors are not targeted by the WFD and the GES under the MSFD can only be achieved by taking additional measures.

Habitats Directive, Birds Directive and Natura 2000

The geographical scope of the Birds and Habitats Directives extends to all maritime areas under the jurisdiction of EU member states, including their Exclusive Economic Zones (EEZs). All EU directives, including the Birds and Habitats Directives (shortly 'Natura 2000'), are 'binding, as to the result to be achieved, upon each Member State to which it is addressed'.

Objectives of the Birds and Habitats Directives are expressed in terms of habitat types, habitat species and breeding birds and non-breeding birds. Habitat types link to the habitat level of the MSFD descriptor Biological diversity. Species and birds of the Directives link to the species level of the MSFD descriptor Biological diversity.

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[2] *Both the WFD and the MSFD use the acronym GES for their objectives. Thus two different GES targets will apply in the same water body. The now established use of the acronym 'GES' in coastal water bodies under the WFD refers to a carefully defined biological objective taking into account physical-chemical and hydro-morphological parameters. GES under the MSFD is much broader.*

For the analysis of current environmental status, important features and characteristics, impact of pressures and progress towards the GES habitat types and the population dynamics of species identified under the Habitats and Birds Directives, should be addressed. This relates to the analyses that are the basis for the Eco-point method of the North Sea.

Furthermore, the obligation to designate Natura 2000 sites under the Habitats and Birds Directive will make an important contribution towards achieving several goals of the MSFD. Programmes of measures of the MSFD should include spatial protection measures (representative networks of marine protected areas) including special areas according to the Habitats and Birds Directive.

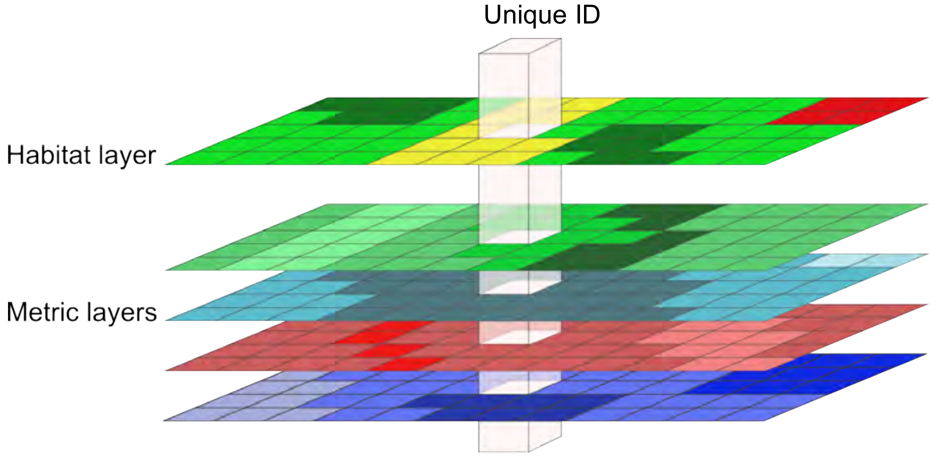
In the Dutch part of the North Sea, three areas are designated as Natura 2000 areas: the coastal zone; the 'Voordelta'; and the 'Vlakte van de Raan'. In 2012, three more areas will be added: the 'Friese Front'; the 'Klaverbank'; and the 'Doggersbank'. As part of the designation process for areas protected under Natura 2000, a number of studies have been conducted that focus on the present status of these areas and their management objectives. The Voordelta is the only area for which formal objectives and related measures have been formulated in an approved management plan (www.synbiosys.alterra.nl/natura2000).

Convention on Biological Diversity

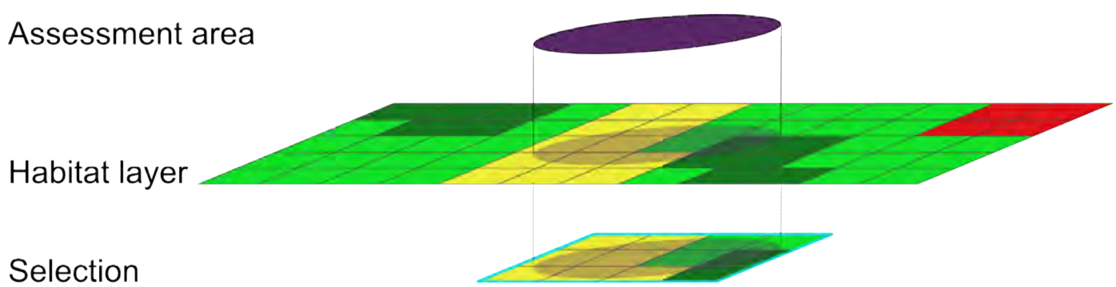
As explicitly mentioned in the MSFD (2008/56/EC) the directive should support efforts in reaching goals stated by the Convention of Biological Diversity (CBD) and its objectives of Conferences of the Parties. Signed by 150 government leaders at the 1992 Rio Earth Summit, the Convention on Biological Diversity is dedicated to promoting sustainable development. Related objectives are for example, halting biodiversity loss, ensuring the conservation and sustainable use of marine biodiversity, and on the creation of a global network of marine protected areas by 2012.

Appendix 5: Technical application

All data processing is based upon a pile of vector-layers configured out of 5x5km raster features. Every cell is uniquely addressed over all layers, so every single cell value can easily be updated by some simple SQL-script (database processing commands).



Step 1) Spatial selection of affected habitat cells. This can be done by manually selecting 5x5 cells or by a spatial selection based on a pre-defined study area. In both cases the selected cells are written to a geodatabase.

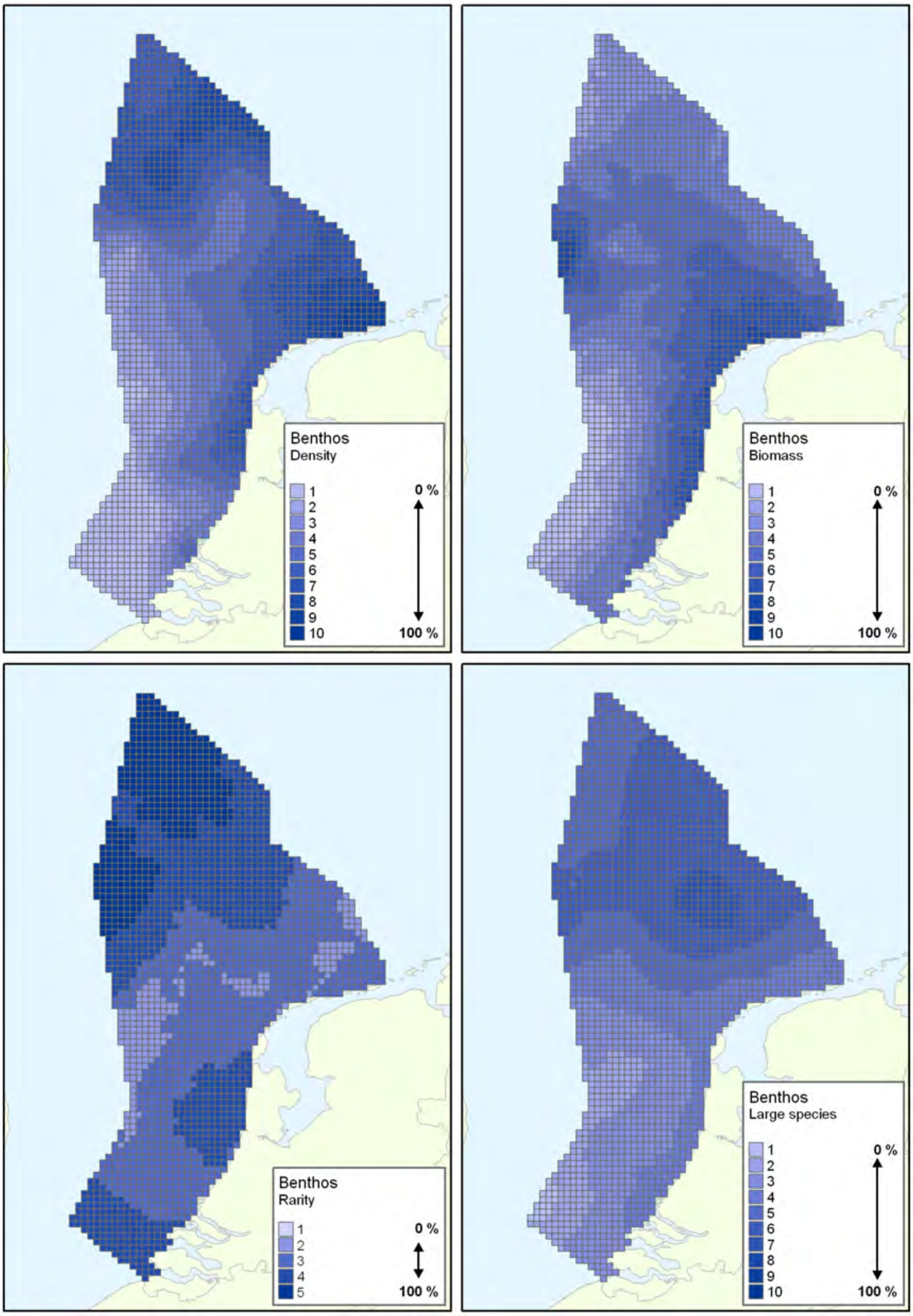


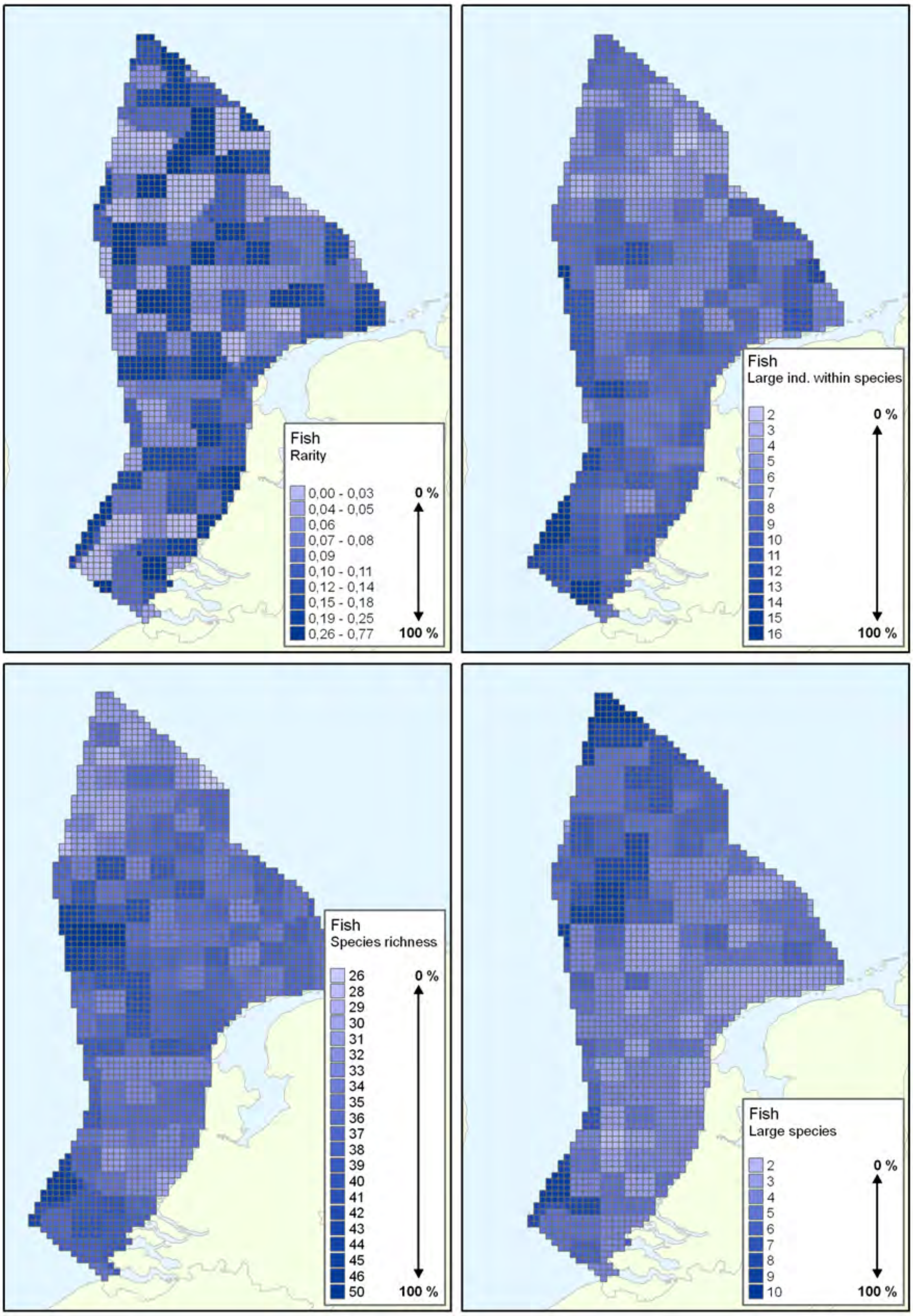
Step 2) Input of correction values for each individual metric per habitat due to the proposed measure. Correction values are processed as percentage increment or decrement of the original quality.

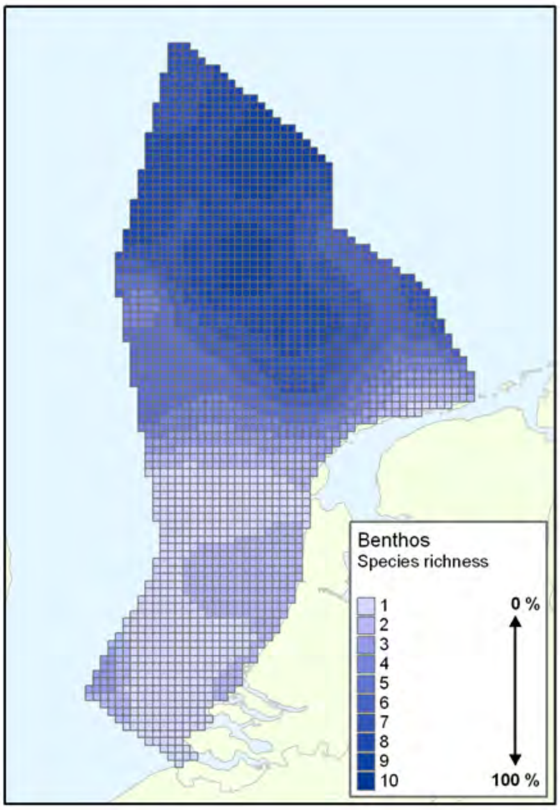
Step 3) During pre processing every selected cell is updated with the corrected value in each metric layer.

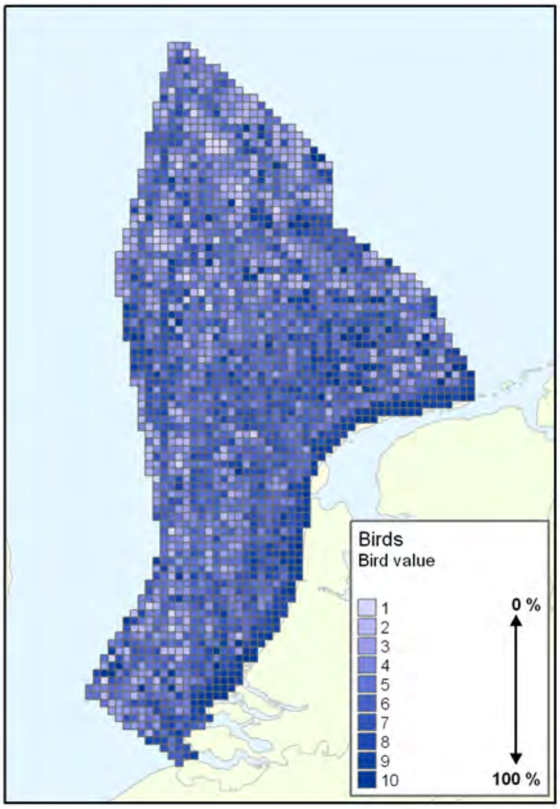
Appendix 6: Eco-point metric maps

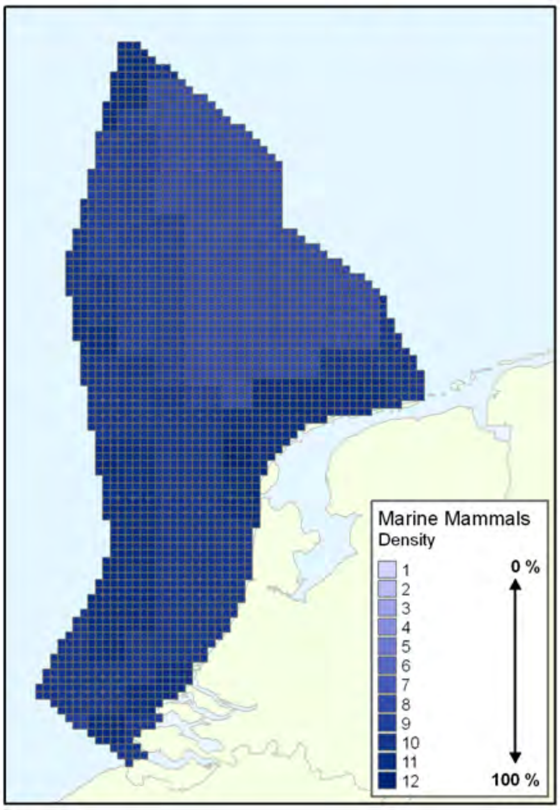
(Data source: IMARES)




Fish
Rarity
0,00 - 0,03
0,04 - 0,05
0,06
0,07 - 0,08
0,09
0,10 - 0,11
0,12 - 0,14
0,15 - 0,18
0,19 - 0,25
0,26 - 0,77
0 %
100 %
Fish
Large ind. within species
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
0 %
100 %
Fish
Species richness
26
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
50
0 %
100 %
Fish
Large species
2
3
4
5
6
7
8
9
10
0 %
100 %


Benthos
Species richness
1
2
3
4
5
6
7
8
9
10
0 %
100 %


Birds
Bird value
1
2
3
4
5
6
7
8
9
10
0 %
100 %


Marine Mammals
Density
1
2
3
4
5
6
7
8
9
10
11
12
0 %
100 %

Appendix 7: Long list of measures

Long list of measures. The measures taken into account by Reinhard (et al. 2011) are shaded.

	Measure
1	Active elimination of newly introduced species in yacht harbours
2	Mandatory regular cleaning of sea chests, hull & propeller
3	Additional N-reduction
4	Implementation of more selective fishing methods
5	Replacing conventional beam trawl with the Pulswing technology
6	Closed areas for fishing in offshore wind parks
7	Closed areas for bottom trawling in offshore wind parks
8	Zoning of bottom trawling outside of Natura 2000 areas
9	Fisheries zoning inside Natura 2000 areas based on the impact of fishing techniques and the type of habitat
10	Combination of zoning and access to those fishing areas for specific fishing methods
11	Fisheries zoning outside of Natura 2000 areas based on the impact of fishing techniques and the type of habitat
12	Discard ban on all commercial quota- and non-quota species
13	Discard ban on all species caught
14	Cleaning production mud
15	Stricter enforcement, higher penalties pollutors
16	extending dumping bans lipophyllic substances
17	Different packaging standards of plastic pellets
18	Alternative for bundles of nylon wires used to protect fishing gear
19	Biodegradable nets
20	Higher fines for littering
21	Real-time management of noise pollution in time and space
22	Enforcing JNCC marine mammal protocol seismics
23	Silent construction methods
24	Use of acoustical scaring devices and ramp-up
25	Stimulating the usage of (diesel-)electric marine propulsion
26	Using green lights on offshore platforms
27	Observers and/or camerasystems on set-net vessels
28	Supplementary feeding of gull chicks
29	Zoning tourism
30	Ban on imports of ALL exotics for aquaria
31	Ballast water treatment on all large ships
32	Prevention of non-indigenous species entering Dutch waters through shell imports from outside of the North Sea
33	Pole and cover stones inspections and cleaning
34	Certification of the fisheries chain
35	Reduction of fishing effort
36	Land base communal Water Treatment Plants: extra P to sea
37	Different river water management (directing river outputs in case of calamity)
38	Stricter restrictions on sea based dumping of dredged material
39	Additional P-reduction Water Treatment Plants
40	Additional reduction contaminants Water Treatment Plants
41	Deeper sand burrows
42	Ecological landscaping burrow pits
43	Limiting silt plumes by limiting silt overflow
44	Reduction of quota
45	Reduction of shell mining in Natura 2000 sites in the coastal zone
46	Zoning of dumping areas/reuse
47	Natura 2000 coastal zones: sea-bottom protection zones
48	(temporary) Zones with reduced frequency of certain fishing techniques outside of Natura 2000
49	Meganourishments in the coastal zone
50	Sand-efficient coastal strategies
51	Introducing hard substrate items in bottom-protection zones
52	More calamity control
53	Zoning of oil & chemical spills clean-ups (uitsplitsen naar scheepvaart en boorplatforms)
54	Zoning of oil & chemical spills clean-ups (related to shipping)
55	Zoning of oil & chemical spills clean-ups (related to oil drill platforms)
56	stricter enforcement, higher penalties deep water shipping lanes
57	Additional public campains on litter
58	Ban on use of plastic bags in supermarkets

59	Do it yourself beaches
60	Biodegradable user plastics at beaches
61	Biodegradable balloons, balloon valves and ribbons
62	Stricter enforcement on the use of port reception facilities to collect waste
63	Fishing for litter
64	Adding indiviually recognisable ID-markers to fishing nets and wires
65	Additional Beach cleaning
66	Deposits on all plastics
67	Noise reduction in shipping
68	Management of active sonar use
69	Implementation of silent gear boxes in turbines
70	Reduction of noise emissions by seismic survey (level of duration) + detonation of munition
71	Natura 2000 coastal zones: recreational zoning
72	Dredging of contaminated sediments

Acknowledgements

The Eco-point study presented here is the fruit of cooperation between the Ministry of Infrastructure and the Environment, the Rijkswaterstaat Centre for Watermanagement (Dutch: Waterdienst) and the PBL Netherlands Environmental Assessment Agency (Dutch: PBL, Planbureau voor de Leefomgeving), represented by respectively mr. Wim van Urk, mr. Rob van der Veeren and mr. Rick Wortelboer. Rob van der Veeren (Watertdienst) had an important role as the project manager of this complex study. Rick Wortelboer (PBL) contributed for a large part to the development of the Eco-point North Sea concept. In addition the authors want to thank mr. Oscar Bos from IMARES for his kindness to bring the data of his ‘hotspots’ study (Bos *et al.* 2011) to our disposal, as well as mr. G. van Moorsel for supplying us with information on the Cleaverbank monitoring data.

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