# A ranking of coastal EU habitat types using Ecosystem Services

S.R. Smith, C. Deerenberg

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IMARES Wageningen UR

Institute for Marine Resources & Ecosystem Studies

Client: Ecoshape / Building with Nature
Burgraadt Gebouw
Burgemeester de Raadtsingel 69
3311 JG Dordrecht

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P.O. Box 68
1970 AB IJmuiden
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 26
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 77
4400 AB Yerseke
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 59
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 57
1780 AB Den Helder
Phone: +31 (0)317 48 09 00
Fax: +31 (0)223 63 06 87
E-Mail: imares@wur.nl
www.imares.wur.nl

P.O. Box 167
1790 AD Den Burg Texel
Phone: +31 (0)317 48 09 00
Fax: +31 (0)317 48 73 62
E-Mail: imares@wur.nl
www.imares.wur.nl

# Summary

Human activities in the coastal area, such as coastal development and hydraulic engineering infrastructural works often result in changes in coastline habitats. Often these changes are seen as negative effects on the ecosystems, especially when the effects concern Natura 2000-areas, which are protected in The Netherlands by the Nature Conservation Act (NCAct). However, during hydraulic works, it is not uncommon that interchanging of habitat types occurs through partial area loss of the habitat type at the location of the activity and development of new habitat or enhancing the quality of the same of another habitat type elsewhere. According to the current interpretation of the NCAct legislation, replacement of area or quality of one (protected) habitat type by another does not compensate for the surface area lost, although it is conceivable that this replacement does not result in a reduction of the overall value of nature of the area or site and may even lead to an improved overall value. If so, the activity would be coherent with the overarching aim of the Habitats Directive and the Natura 2000-network, i.e., to assure the long-term survival of Europe's most valuable and threatened species and habitats. Currently, however, The NCAct focusses on restricting negative effects on conservation aims of protected areas and potential positive effects are hardly considered (if at all).

The value of nature of habitat can be viewed by the intrinsic natural values of the habitat, defined by the ecosystem structure, processes and functions, and by its potential extrinsic values or ecosystem services, defined by those ecological phenomena that can be used by humans. In the present study, both views on the value of nature (intrinsic and extrinsic values, i.e., natural values and ecosystem services) are combined in a qualitative assessment to produce a rough estimate of the overall natural value of each of the Dutch coastal habitat types, that have to be protected according to the Habitats Directive. Based on their thus assessed overall natural value, a general ranked list is made of these protected habitat types. The overall ranking, whether based on combined or separate values, gives a first impression of potential to increase the value of nature of an area. The separate ranking and underlying (qualitative) assessment allows specification of which values and to what extent may change (due to an activity) and thus identifies potential trade-offs between various aspects of the value of nature. The here described method may thereby therefore provide a basis for informed decisions about human activities that result in an exchange of surface area and/or quality of protected habitats.

A total of 14 Dutch coastal habitat types have been defined, some of which are differentiated into several subtypes. Including subtypes, the Dutch coastal habitats comprise 26 types (Table 3). The rating of the coastal habitats from the viewpoint of their intrinsic underlying natural value, is based on the four aspects of the national conservation status (i.e. range, surface area, quality and prospects), as mentioned in the profile documents for these protected habitats (Ministerie LNV, 2008). Based on these four aspects concerning their intrinsic natural values, it appears that habitat types H2180 A (dry wooded dunes), H2170 (dunes with *Salix*), H2150 (Atlantic decalcified fixed dunes), H2110 (embryonic shifting dunes), H1310 B (annual colonizing mud & sand) and H1140 B (coastal zone mudflats and sandflats not covered by seawater at low tide) score highest on the ranked list. In contrast, H1320 (*Spartina* swards) and H2130 (fixed coastal dunes with herbaceous vegetation) score low on the ranked list (Table 4).

The rating of the coastal habitats concerning their contribution to the extrinsic value of nature, as assessed by their provision of ecosystem services, is based on seven categories of ecosystem services; food provision, raw materials, gas and climate regulation, disturbance prevention (flood and storm protection), bioremediation of waste, cognitive benefits, and leisure and recreation. For each habitat, each category is assigned a numerical score, based on the perceived potential of the habitat type to provide this ecosystem service. From the viewpoint of the extrinsic value of nature as assessed by ecosystem services, it appears that habitats H1110 (sandbanks which are slightly covered by seawater

all the time) and H1140 (mudflats and sandflats not covered by seawater at low tide) score highest on the ranked list. In contrast, habitats H2120 (shifting dunes along the shoreline with *Ammophila arenaria*), H2190 (humid dune slacks) and H2110 (embryonic shifting dunes) score low on the ranked list (Table 6).

The assessments of the value of nature of the coastal habitats and the resulting ranked list based on their intrinsic natural values and extrinsic  ecosystem services are combined in an overall natural value (Table 7). It appears that H1140 (mudflats and sandflats not covered by seawater at low tide) and H1110 (sandbanks which are slightly covered by sea water all the time) provide the highest overall value of nature, in contrast to H2130 (fixed coastal dunes with herbaceous vegetation ('grey dunes') and H2190 (humid dune slacks), which appear relatively low in overall value of nature.

*Note: The ranked list obtained is qualitative and provisional, because the assessment of the ecosystem services is based on the (limited) expert judgement of the authors. This study shows the first exploratory steps of combining intrinsic an d extrinsic values of nature and the method thus requires further development. The method does give, however, a first impression of the added insights of combining these two aspects of the value of nature and which Dutch coastal habitat has a relatively high overall natural value and which has a lower overall natural value.*

# Contents

# Disclaimer

In this report, we develop and describe a method to assess and rate ecosystem services (including natural values) of Dutch coastal habitats. We combine these ratings to arrive at a ranking of the various coastal habitats. The focus of this report is on the method. The here described realized assessment, rating and ranking exemplifies the method developed, but is not completely based on objective criteria. Rather, it uses 'a' classification of ecosystem services and natural values and the rating is based on the common ecological knowledge of the authors (who are not experts on coastal habitats). The results are therefore indicative and aimed at exemplifying the developed method, rather than resulting in a definite ranking of the habitats.

# 1 Introduction

## 1.1 Background

The programme “Building with Nature” was initiated by the foundation Ecoshape in 2008 with the aim to develop new ways of thinking and acting in relation to sustainable coastal development (IADC, 2010). “Building with Nature” is an approach to plan, design and operate hydraulic engineering infrastructural works and coastal development using natural forces and simultaneously create new opportunities for nature. Maritime infrastructure often changes the coastline, and the “Building with Nature” principle aims at showing that such changes are not necessarily detrimental to the natural world. Such changes, when implemented properly, may actually improve ecological conditions, e.g., attract new species or provide new habitats, and socio-economic needs, e.g., coastal protection and recreational infrastructure (IADC, 2010).

During hydraulic engineering works, it is not uncommon that interchanging of habitat types occurs, either through partial area loss of one habitat type and creation of new or additional habitats, or through the enhanced quality of another habitat type. In Europe, large parts of many coastal habitats are protected under the EU Habitats Directive (92/43/EEC, 1992), which in the Netherlands is elaborated in national legislation in the Nature Conservation Act 1998 (NCAct). The Habitats Directive requires the establishment of Special Areas of Conservation (SACs) to be designated for species other than birds, and for habitats. SACs make up the EU-wide Natura 2000-network of protected areas, together with Special Protection Areas (SPAs) for birds, that are based on the EU Birds Directive (79/409/EEC, 1979). National conservation objectives for habitats in the Netherlands are set out in the Natura 2000 targets document (‘Doelendocument’, LNV, 2006), and site-specific conservation objectives are laid down in the Designation Order (Aanwijzingsbesluit) for a site. The NCAct dictates that activities with potentially ‘significant’ negative effects on the conservation objectives for the protected habitats (and species) of a Natura 2000-site are required to apply for a license from the relevant planning authority. Especially when infrastructural works and coastal development are to take place at or nearby or with influence on Natura 2000-sites, current legislation may impede the implementation of the hydraulic engineering project, owing to the loss of area of a protected habitat type.

In general, positive effects are not considered in the assessment in the context of an NCAct license. Only if a Designation Order specifically uses the formulation ‘in favour of’ (another habitat type), negative impacts on –specifically indicated– other protected habitat types are allowed (Regiegroep Natura 2000, frequent questions: http://www.natura2000.nl). Only when the activity has stringent public importance it is allowed to compensate habitat loss, e.g., by developing the lost habitat type elsewhere or enhancing its quality.

According to the current interpretation of the NCAct legislation, replacement of area of one (protected) habitat type by another does not compensate for the surface area lost. However, it is conceivable that the replacement of one (protected) habitat type by another leads to an improved overall natural value of the area or site. This would be coherent with the overarching aim of the Habitats Directive and the Natura 2000-network, i.e., to assure the long-term survival of Europe's most valuable and threatened species and habitats.

The legislation suite of EU Habitats Directive and national NCAct aiming at protecting habitats is motivated by the intrinsic natural value of these habitats and is based on the Convention of Biological Diversity (CBD) (Rio de Janeiro, 1993). In addition, natural habitats include a wide range of resources and processes that may be consumed or utilized by humanity. This concept of benefits to humans has been named ‘Ecosystem Services’ (e.g., Costanza et al., 1997, Daily, 1997, see also paragraph 2.1). Different natural habitats may provide different ecosystem services (see e.g., Beaumont et al., 2007 for ecosystem services provided by coastal habitats), and habitats may differ in their potential to supply ecosystem services. Ecosystem services add additional, extrinsic value to natural habitats and the concept of ecosystem services may be used in acknowledging the overall value of natural habitats or in evaluating the impacts of activities on the habitats.

## 1.2 Aim

At present, the impact of hydraulic works on nature are often evaluated using ecosystem services in a cost-benefit analysis, in terms of financial values. In contrast, the impact on the underlying natural values itself is usually evaluated in an non-monetary qualitative or semi-quantitative environmental impact assessment (EIA). The present study explores the possibility to explicitly combine the impacts on the underlying natural values and those on the ecosystem services into one methodology, thus simultaneously and in a comparable manner. Hydraulic works potentially result not only in negative effects, but also in positive effects on both natural values and the ensuing ecosystem services. Given this potential, the combined approach should produce a final balance of the impacts, while specifying and clarifying the elements that result in these expected final consequences for the overall natural value. The aim of this combined approach is to do justice to expected positive effects on nature.

The present study therefore aims at:

- Conceptualizing a method that lists and values qualitatively ecosystem services as well as the underlying natural values of (coastal) habitats;
- Applying this method to produce a rough estimate of the overall natural value of each of the various Dutch coastal habitat types that have to be protected according to the Habitats Directive;
- Making a general ranking of these habitat types based on the overall natural values of each habitat.

Such a methodology, including the ranked list, may support prior effect assessment of e.g., hydraulic works according to the Building with Nature principle. The ranked list gives a first impression which habitat has a relatively high overall natural value and thus may withstand some negative impact, whereas habitats with a lower overall natural value may benefit from positive effects of a proposed activity. The underlying conceptualized method allows detailing of the various potential impacts of the activity and thereby gives evidence for a balanced trade-off. In the end this method may help to improve the selection of the best scenario for a planned activity by also taking into account potential positive effects rather than only prevent and avert negative impacts.

## 1.3 Approach

To rank habitats based on their ecosystem services, we first reviewed current definitions of ecosystems services and methods to value nature based on ecosystem services. Subsequently, we outline an approach to value habitats. We then applied this valuation approach to Dutch marine coastal habitats, to end up with an overall value for each habitat type. These overall values were then ranked. During this process of reviewing ecosystem services to value nature and developing the ranking methodology, we discuss limits and considerations encountered.

# 2 Assessment of value

## 2.1 Ecosystem services and natural values

### 2.1.1 Definitions

Humans have always benefited from a wide range of resources and processes that occur within natural ecosystems. Such natural benefits, which may be provided as goods (e.g., fish, gravel) or services (e.g., clean water provision), are collectively known as ecosystem services. The concept of ecosystem services has been a focus of research since the end of the previous century (e.g., Daily, 1997; Costanza et al., 1997; Boyd and Banzhaf, 2007; Wallace, 2007). In 2000, the United Nations General Assembly called for the Millennium Ecosystem Assessment (MEA) to assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being. It was during this four-year study, initiated in 2001 and which involved 1,300 scientists worldwide, that ecosystem services were popularized and their definitions formalized (MEA, 2003).

The Millennium Ecosystem Assessment defined ecosystem services as '*the benefits* people obtain from ecosystems' (MEA, 2003). However, the definition of ecosystem services by the MEA was not the first attempt to do so. The MEA was preceded by attempts of amongst others Pearce & Turner (1990; 'economic value'), Daily (1997), Costanza et al. (1997) and De Groot et al. (2002). Boyd & Banzhaf (2007), Wallace (2007) and Fisher & Turner (2008) all agree that the MEA definition and elaboration is insufficient to be used in practical accounting exercises or landscape management. They argue that processes (the means of delivering services) are mixed with the services themselves, allowing the risk of double counting. Double counting occurs when both intermediate services or products and final services or products are valued. Table 1 shows the differences and similarities between the studies of MEA (2005), Boyd & Banzhaf (2007), Wallace (2007) and Fisher & Turner (2008).

Boyd & Banzhaf (2007) define ecosystem services based on economic principles. They see ecosystem services as ecological components (e.g., lakes, forests, fish populations), that are separate from benefits and which have to be utilized directly (e.g., clean drinking water). They see benefits as the combination of ecological components and conventional goods/skills (e.g., the benefit angling is a combination of the ecosystem services surface water and fish populations with the conventional goods and services such as tackle, boats, access, etc.; Boyd & Banzhaf, 2007). Wallace (2007) agrees with Boyd & Banzhaf (2007) in that ecosystem services should be utilized directly, however they do not limit ecosystem services to being ecological components. Both differ from the general classification of MEA (2005) as their ecosystem services can be benefits, can be used indirectly and are not limited to ecological components alone, but may also comprise ecosystem processes and functioning, such as flood regulation. In addition, MEA (2005) views non-ecological concepts such as aesthetic value, recreation and cultural contentment also as ecosystem services. Fisher & Turner (2008) do not restrict ecosystem services to be used directly, and they separate the services from the benefits, similar to Boyd & Banzhaf (2007). Fisher & Turner (2008) also agree with Boyd & Banzhaf (2008) that ecosystem services are ecological in nature, but do not think this has to be limited by ecological components alone; they state that processes and functions can be ecosystem services too, as long as there are people that can benefit from them.

*Table 1 An overview of the similarities and differences among four ecosystem service definitions*

| **Statement** | **MEA (2005)** | **Wallace (2007)** | **Boyd & Banzhaf (2007)** | **Fisher & Turner (2008)** |
|---|---|---|---|---|
| Ecosystem services should be utilized directly | no | yes | yes | no |
| Services are not benefits | no | no | yes | yes |
| Ecosystem services are ecological in nature | not necessarily | not necessarily | yes | yes |
| Ecosystem services are ecological components | inapplicable | inapplicable | yes, ecological components (lakes, fish, forests, things you can count) | not necessarily, functions and/or processes can be ecosystem services as long as there are human beneficiaries |

Fisher et al. (2009) propose a conceptual relationship between ecological phenomena and the various aspects of ecosystem services (intermediate and final services and benefits). In their definition, the ecological phenomena comprise ecosystem organization or structure as well as ecosystem operation, i.e., processes and/or functions. They define ecosystem services as those ecological phenomena, that are directly or indirectly consumed or utilized by humanity. These interdependent relationships are comprehensibly depicted in Fig. 3.1 of TEEB's Interim Report (2008) and further developed in Fig. 2 of UNEP-WCMC (2011), which term the ecological phenomena biological structure or process and (ecosystem) function (Figure 1). TEEB's (2008) and UNEP-WCMC's (2011) term "function" overlaps with the term "intermediate services" of Fisher et al. (2009). According to Fisher et al. (2009) final ecosystem services result in benefits only when they are put to use through other forms of capital, e.g., fishery requires vessels, fuel and gear to catch the fish, whereas TEEB (2008) define benefits as the monetary value of ecosystem services and UNEP-WCMC (2011) separates the economic value from the benefits. These ways of organizing these aspects are broadly similar, however, and allow to determine how and through which relationships (final) ecosystem services and ensuing benefits are made available by a certain habitat type.

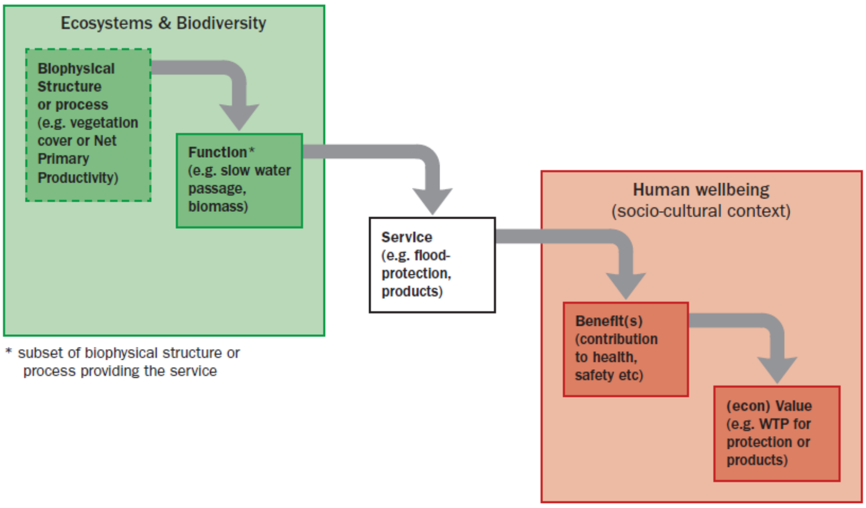


*Figure 1 Framework for linking ecosystems to human well-being. Source: Fig. 2 from UNEP-WCMC (2011).*

Valuing ecosystems by ecosystems services, means that the value of nature is linked to the premise that humans may make use of it. Whereas ecosystems have components that have ecological, social, economic, scientific, educational, cultural, recreational and aesthetic value, they also have an existence value (Pearce & Turner, 1990) or intrinsic value (Gross, 2006). These intrinsic natural values can be classified as e.g., supporting ecosystem services (MEA, 2005) or option use value (Pearce & Turner, 1990; see paragraph 2.1.2). However, both MEA (2005) and Fisher et al. (2009, referring to Turner, 1999) viewed these intrinsic values as an underpinning or necessary infrastructure for the potential occurrence of ecosystem services. According to this concept, ecosystem services, i.e. the services potentially used by humans, are a subset (in the mathematical definition) of the larger set of all ecological phenomena constituting the functioning of an ecosystem and thus the intrinsic natural values or supporting services of an ecosystem. In nature conservation, currently in Europe elaborated by the Habitats Directive and the Natura 2000-network, habitat types are valued and their conservation status is assessed on these intrinsic natural values or supporting services only.

We think that the concept by Fisher et al. (2009) distinguishing intermediate services, final services and benefits and the additional separation into extrinsic ecosystem services (i.e., used by humans) and intrinsic natural values or supporting services is useful, if not necessary when evaluating the effects projects on habitats using ecosystem services. It enables the analysis of the final services that will be lost or gained owing to the loss or gain of an intermediate service, after which the separate consequences for either the conservation status (based on all intrinsic natural values) or human use (based on the subset of extrinsic ecosystem services) can be assessed.

### 2.1.2 Classification

Multiple categories of ecosystem services have been distinguished, depending on the definitions used for ecosystem services (Costanza et al., 1997; MEA, 2003; Hein et al., 2006; Boyd & Banzhaf, 2007, Beaumont et al., 2007; Wallace, 2007). De Groot et al. (2002; ‘functions’) and MEA (2003; ‘services’) subdivided the ecosystem services similarly into four categories:

- *Provisioning or production services* as the goods and services or natural resources produced in the ecosystem. For example, fish of marine ecosystems and edible halophytes (*Salicornia*) of marshes.
- *Regulating services*, resulting from the capacity of ecosystems to regulate essential ecosystem processes. For example, water regulation by dunes resulting from to storage and purification of water.
- *Cultural or information services* as the nonmaterial benefits obtained through recreation, cognitive development, relaxation and spiritual reflection. For example, wildlife watching.
- *Supporting of habitat services* as those processes necessary for the production of all other ecosystem services. The impacts of supporting services on people are often indirect or occur over a very long time. For example, habitat provision for wildlife, or sediment transport by waves and currents. In this report we use the term intrinsic ecosystem services or natural values for this category.

The MEA classification is widely used, often with adaptations. The differences that exist in ecosystem service classification stem from the fact that ecosystem services classification schemes are based on the specific contexts in which they are used as well as the definition used (Fisher & Turner, 2008).

In most papers, the ecosystem services classifications have been applied to terrestrial habitats. Identified and defined ecosystem goods and services provided by marine biodiversity and European seabed biotopes have been described and discussed by Beaumont et al. (2007) and Salomidi et al. (2012), respectively. The classification of Beaumont et al. (2007) follows MEA (2003) as they divide goods and services into the four categories production, regulating, cultural and supporting services. They added the category ‘Option use value’ with the accompanying service of future unknown and speculative benefits.

The list of ecosystem services (without classification) of Salomidi et al. (2012) is to a large extent similar to the list of Beaumont et al. (2007).

Applying the distinction between intrinsic natural values and extrinsic ecosystem services retrospectively to the classification proposed by MEA (2003), the supporting services constitute intrinsic natural values, the provision or production services and regulation services fall into the definition of extrinsic ecosystem services, whereas cultural services and option use value (added by Beaumont et al. 2007) constitute benefits in the sense of Fisher et al. (2009).

## 2.2 Valuation methods

Nowadays, when discussing biological or biodiversity valuation the chances are high it concerns the economic value of biodiversity, the monetisation of nature (monetary methods). Valuating nature by giving it a monetary value started an intense discussion on the risks such actions may have on turning nature into a tradable commodity. The purpose of monetising nature lies in the need to take into account the effects on nature when possible alternative scenarios in spatial planning are being weighed by politicians in determining the right course of action. Weighing alternative scenarios and their effect on nature is often done in a cost-benefit analysis or a cost efficiency analysis. An example of how the importance and value of nature can be highlighted is when the costs of maintaining a mangrove forest, with the additional benefit of coastal protection it provides, are compared to the costs made when a man-made construction needs to be realised and maintained to guarantee the same degree of coastal protection. More often than not, the costs of realizing and maintaining such a construction are disproportionately high compared to the costs of maintaining the mangrove forest. The monetisation of nature values can be very useful in keeping things in perspective. However, the effects on some of the categories of ecosystem services, especially the supporting services or intrinsic natural values are (too) difficult to monetize, resulting in their inadequate inclusion when deciding on a course to take.

Economic (monetary) valuation methods, such as the Total Economic Value (TEV) approach (Fig. 2 of UNEP-WCMC, 2011), attempt to assess the value or cost of ecosystem goods and services, to be expressed by willingness to pay (WTP) or willingness to accept (WTA; Pearce & Turner, 1990). Contrary to what its name suggest, the TEV approach measures choices or trade-offs between alternative states, not the overall economic value of an ecosystem. The Total Economic Value is categorized into components that contribute to the total economic value and consists of use- and non-use values (Figure 2). The use values comprise Actual use value, either direct (e.g., consumption of food products or recreation) or indirect (e.g., climate regulation) and Option use value (i.e., unused or future potential). The non-use value consists of Existence value (i.e., knowledge of the existence and conservation of ecosystems). As a result of the on-going and expanding field of the economic valuation of ecosystems, an international initiative has been set up, The Economics of Ecosystems and Biodiversity (TEEB, www.teebweb.org), that draws attention to the global economic benefits of biodiversity. TEEB focusses on bringing together expertise from the fields of science, economics and policy. The approach adopted by TEEB is to show how economic concepts and tools can help equip society with the means to incorporate the values of nature into decision making at all levels. (TEEB, 2012).

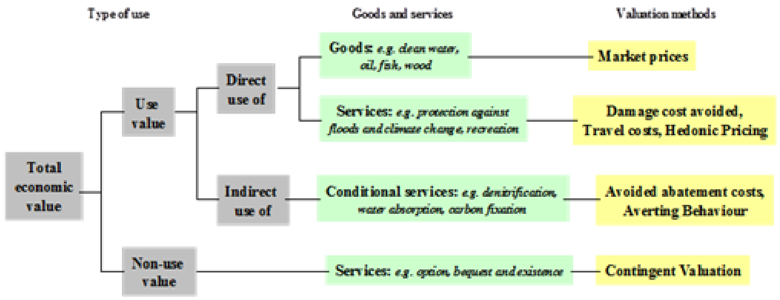


*Figure 2 Components of total Economic Value (Figure by courtesy of R. Abma, W&B)*

Valuation of ecosystem services methods can also be done using non-economic valuation methods by confining the valuation to the underlying quantitative and/or qualitative assessments of the monetary methods (see for a hierarchical overview of a valuating system Figure 3.2 in TEEB, 2008). In contrast to monetary economic methods, non-economic methods assign values to biodiversity according to its qualities or attributes and often comprise ecosystem indicators as proxies for ecosystem services. Non-economic methods comprise in addition to quantitative methods (e.g., the number of birds) also semi-quantitative or qualitative assessment methods. Non-economic methods can be applied to value the ecosystem services (extrinsic values) as well as the supporting services or natural values (intrinsic values) or environmental or biodiversity assessment in general (Málovics & Kelemen, 2009).

We here give a brief overview of the monetary economic (paragraph 2.2.1) and non-economic (paragraph 2.2.2) methods that are applied to assess the value of ecosystem services.

### 2.2.1 Economic (monetary) valuation of ecosystem services

The literature on the valuation of ecosystem services comprises numerous articles on economic (monetary) valuation of ecosystem services (e.g. Hanley & Spash, 1993; Costanza et al., 1997; Bartelmus, 1997; Daily et al., 2000; Baarsma, 2003). Of these, the work by Costanza et al. (1997) is a review of the valuation of a wide variety of ecosystems. Among the various economic valuation methods that have been developed to estimate the economic monetary value of an ecosystem service, a distinction is made between market-based techniques, revealed preference and stated preference methods (UNEP-WCMC, 2011). Market-based techniques use evidence from markets to obtain a value for the goods and services of ecosystems. Revealed preference techniques are based on deducing the value of ecosystem services by interpreting observed human behaviour. Stated preference techniques are based on surveying representative samples of a population in order to estimate willingness to pay for hypothetical changes in ecosystem services. Eftec (2006), Defra (2007), Haines-Young & Potschin (2009) and UNEP-WCMC (2011) give overviews of the different methods used for valuation of ecosystem services. Because the present study focusses on the valuation of ecosystem services using a non-monetary method, only a few methods of monetary valuation of ecosystem services are addressed below.

*Marked-based methods*

- The *Market prices method* uses the economic values (prices) for ecosystem products or services that are bought and sold in commercial markets (Carson & Bergstorm, 2003). An example would be estimating the market value of fish within a certain area.
- The *Replacement cost method* looks at how much it would cost to replace an ecosystem service with a man-made service (UNEP-WCMC, 2011). An example is how much it would cost to replace a

mangrove forest with man-made structures to obtain the same level of coastal protection or erosion control.

*Revealed preferences methods*

- The *Production function method* looks at how physical effects of a change in a biological resource influence an economic activity (Barbier, 1994). This method is used to value indirect use values, values derived from the indirect use of a good or a service (e.g. lower organisms in the aquatic food chain provide indirect use value to recreational anglers who catch the fish that eat the lower organisms). For example, when valuing the service provided by the nursery and breeding habitat function of coastal wetlands for commercial near-shore fisheries. By estimating the impacts of the change in the coastal wetland area on fishery catch, it is possible to estimate how these impacts influence the costs of fishery harvests (Barbier, 2007).
- The *Hedonic pricing method* looks at how the occurrence of certain ecosystem services, as characteristics, affect the prices of marketed goods (King & Mazzotta, 2000). For example, the effect of the availability of aesthetic view on housing prices. This method is used to estimate economic benefits/costs associated with environmental quality (e.g., pollution and environmental amenities, such as aesthetic view).
- The *Travel cost method* looks at the travels costs people are willing to pay to travel in order to enjoy a certain ecosystem service (King & Mazzotta, 2000). An example is how much visitors are willing to travel to a wetland area in order to watch birds.
- The *Averting Behaviour method* looks at how much individuals would be willing to pay to avoid negative effects on the environment (e.g. pollution; Whitehead & Van Houten, 1997). This method can be used to analyse services related to purification services of some ecosystems (Harford, 1984 as mentioned in Lin et al., 2011).

*Stated preferences methods*

- The *Contingent valuation method* comes down to asking people how much they would be willing to pay for a specific ecosystem service (Carson & Bergstorm, 2003). This method is often used to obtain a monetary value for non-use values, values that do not involve market purchases and may not involve direct participation. This method was applied in the Building with Nature programme to estimate the willingness of people to pay for actions to preserve nature in the Dutch Eastern Scheldt estuary in view of the negative effects to the estuary resulting from erosion (BwN wiki, 2012).
- The *Conjoint Analysis method* requires individuals to make a choice between two hypothetical environments, in which several attributes are varied (Carson & Bergstrom, 2003). For example, this method was used in a case study in The Netherlands, where artificial islands for residential use were planned in the IJmeer. Conjoint analysis was used to determine the value of recreation (e.g., sailing) and green areas (e.g., waterfowl, plants) as part of the IJmeer that would be lost when the artificial islands were to be built. Alternative scenarios were planned to compensate for these losses (Baarsma, 2003).

### 2.2.2 Non-monetary valuation of ecosystem services and natural values

As shown in the previous paragraph, assigning a monetary value to ecosystem services is a way to compare the value of different ecosystem services. The present section lists several non-monetary methods that can be applied to determine the value of nature by valuing ecosystem services (the extrinsic value of nature) and/or of supporting services or natural values (the intrinsic value of nature; see paragraph 2.1.2).

*Deliberative and participatory valuation methods*

Eftec (2006) describes these (partly overlapping) methods that seek the opinion or preference of experts, the public or stakeholders. They distinguish:

- *Questionnaires and interviews* can give insight into public attitudes, views, behaviour and the reason behind them;
- *Focus groups and In depth groups* are applied to determine, during a discussion, the position or opinion of participants on a pre-defined issue or a set of related issues (e.g., the priority ecosystem services of a specific area) (e.g., Kaplowitz & Hoehn, 2001; Salgado et al., 2009);
- During a *Citizens' jury* a group of citizens discusses about a particular issue or a set of choices based on the evidence provided by experts and stakeholders. The method aims to obtain a carefully considered public opinion (e.g., Aldred & Jacobs, 2000);
- *Health-based valuation analysis* focuses on measuring the value of health impacts based on the impact issues/situations may have on the length and quality of life;
- *Q-methodology* focuses on identifying typical ways people may think about environmental issues;
- *Delphi surveys, systematic reviews* focus on summarizing expert opinion or scientific evidence (cf. expert judgement).

Additional participatory methods are:

- Participatory modelling: workshops in which stakeholders groups collaborate in interactive development of a model (e.g., Videira et al., 2009).
- Scenario workshops: workshops in which stakeholder groups collaborate in defining the key issues of possible future scenarios (e.g., Peterson et al., 2003; Caille et al., 2007).

*Habitat Evaluation Procedure (HEP) and related methods.*

The HEP provides a quantification of wildlife habitat, in terms of Habitat Units, that is based on the measurement of quality (Habitat Suitability Index, HSI) and the total area of available habitat (USFWS, 1980).

- Feather et al. (1995) reviewed monetary and non-monetary valuation methods used in relation to environmental investments. Their non-monetary methods mainly concern the HEP and HEP-related methods, that utilize essentially the same process.
- *The Natural Capital Index (NCI)* originates from concepts developed as a result of the Convention of Biodiversity. Like the HEP-method the NCI is based on combining ecosystem quantity (area) and quality, based on abundance (of species, individuals, etc.). To combine a series of indicators for ecosystem quality, Ten Brink et al. (2000) use the following formula:

  $$\text{NCI or Ecosystem Quality Index} = \sum(1 \text{ to } n)[\text{current state}_n / \text{baselinestate}_n]/n$$

  for n quality variables or indices, resulting in a quality between 0 and 100%.
- *The Eco-points method* is an extension of the NCI and includes a weighing factor to account for the contribution of the ecosystem to biodiversity at a larger geographical scale (Sijtsma et al., 2009).
- *Marine biological valuation* aims to visualize, through maps, the intrinsic value of marine biodiversity, without reference to anthropogenic use. The concept builds on the NCI/HEP method by compiling the indices and plotting them in maps to identify subzones that vary in biological value (Derous et al., 2007a, b).

Feather et al. (1995) point out that the non-monetary methodologies express the evaluation in terms of different units, some use e.g., habitat units, whereas others use surface area or days. Consequently, these methods can be applied to similar environmental alternatives, but they are inadequate when applied to distant or dissimilar ecosystems.

The ultimate aim of measuring the value of the natural environment in financial units is to include this information in the decision-making process. Examples of decision support methods are Cost-benefit analysis (CBA), Cost-effectiveness analysis (CEA) and Multicriteria assessment (MCA). In the current application of CBA to projects in areas with recognised natural values, these natural values enter the CBA usually in one of the following ways: valued according to an ordinal scale and monetised (Sijtsma et al., 2009), or as a P.M.-item (Pro Memorie; under examination). P.M. is often applied when natural values are difficult to express in financial units (e.g. euro's or dollars).

We chose to value nature according to an ordinal scale without monetising, because the focus of the present study was on finding a methodology to combine the value of ecosystem services and natural values.

# 3 Rating and combining intrinsic values and extrinsic services

## 3.1 General description

The aim of this study is to derive a ranked list of coastal habitat types based on the ecosystem services, they provide, i.e., based on the extrinsic value of nature. To do so, it is necessary to compare habitat types by valuing their ecosystem services. However, given that large parts of the coastal habitats are designated Natura 2000-areas, it is imperative that the valuing of ecosystem services of these habitats is combined or integrated with valuation of the intrinsic value of these habitat types that instigated their recognition as important natural areas. In this chapter we described the most basic method of combining or integrating extrinsic and intrinsic values of nature, i.e., ecosystem services and natural values respectively. This approach builds on the existing definitions of ecosystem services (including natural values) and valuation methods that have been described in the previous chapter (Chapter 2). The proposed method is non-monetary and semi-quantitative.

Valuation of habitats can be done based on:

- the intrinsic value of nature, i.e., the natural values, of the habitats, e.g., as appreciated by their conservation objectives (e.g. Sijtsma et al., 2009);
- the extrinsic value of nature, i.e., the ecosystem services of the habitats (e.g., Boyd & Banzhaf, 2007).

Existing methods aiming at valuing nature that use either intrinsic and extrinsic values of nature, or both, fall short, because they are primarily focussed on economic valuation or, more importantly, they are often based on location specific indicators. In this chapter, we therefore aim at assessing the value of natural habitats based on i) (extrinsic) ecosystem services, ii) (intrinsic) natural values and iii) both ecosystem services and natural values combined. The combined assessment of the value of nature allows comparison between habitats and can also be used to generate a ranking of a series of habitats based on their assessed values. The method is general in the sense that it allows both:

- a non-specific use, such as ranking of habitat types, as well as
- custom-made elaboration and detailing, e.g. to assess the overall impact of a specific activity on site-specific values and services.

Using a combined assessment makes it possible to show how the value of the available ecosystem services as well as natural values will change when, for example, one habitat type is replaced by another. Up to now, most assessments have only examined effects of activities on either extrinsic values or intrinsic values, related to the economic context or the nature conservation context of the valuation, respectively. The combined assessment may assist in determining whether effects of an activity, for example a hydraulic engineering project according to the Building with Nature approach, may or may not have an impact on the *overall* recognised value of a natural habitat, e.g. of a Natura 2000-area. When overall valuation of nature by using both natural values and ecosystem services is achieved, including a way to combine these values,

- habitats can be compared and ranked according to their integrated value;
- before-after comparisons can be carried out and;
- overall impacts of a project on an area can be assessed.

To compare and subsequently rank habitat types based on their valued natural values and ecosystem services, the method has to provide for each habitat an overall rating reflecting its potential in providing natural values and ecosystem services. Such an overall rating should be based on separate rating of all natural values and ecosystem services of the habitats. To enable comparing and ranking, we applied a stepwise approach, consisting of three main steps:

1. To identify the various aspects of the habitats that contribute to their natural values and ecosystem services, we first need **an inventory of the natural values and ecosystem services that each habitat potentially can provide**. Natural values and ecosystem services result from biological, chemical and physical processes that occur within the habitat. These biophysical process are enabled by components found within the habitat. Ideally, we would like to assess how and how much a habitat type contributes potentially to each specific natural value and ecosystem service, based on the components it possesses. For example, sea grass fields, shellfish reefs, sand banks and saltmarshes are all components of a coastal ecosystem that may (to some extent) contribute to the ecosystem service coastal protection through the biophysical process wave attenuation. In addition, components itself can contribute directly to ecosystem services and natural values (e.g. mussel beds) (Figure 3).

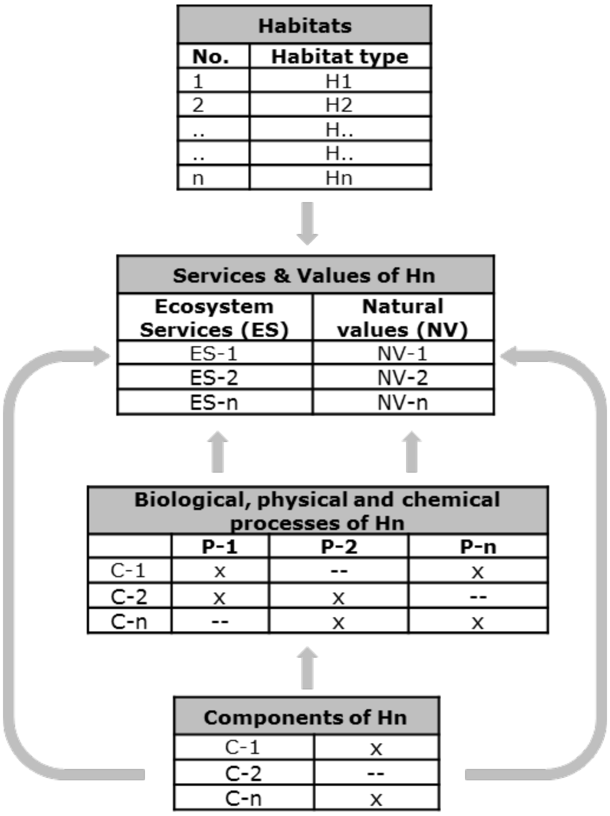


*Figure 3 First step (step 1) of proposed method: to make an inventory of the natural values (NV) and ecosystem services (ES) of several (n) habitats, based on the components (C) of that habitat and the ensuing biological, physical and chemical processes (P).*

2. Secondly, we need to **assess the values (i.e., rate) of each identified natural value and ecosystem service**: the potential or actual contribution of a habitat (when the habitat is in an optimal state and in its current state, respectively) to the various natural values and ecosystem services. To determine the appropriate criteria to value or rate the natural values and ecosystem services, we ideally need a thorough understanding of the components and the related biological, chemical and physical processes that occur within a habitat. In addition, we need to have insight into

the local conditions that shape the site-specific manifestation of both habitat components and biophysical processes. Depending on the available or required knowledge, rating of the identified natural values and ecosystem services of a habitat type can also be based on expert judgement (Figure 4; see for methods paragraph 2.2).

| Value of Ecosystem Services (VES) | | | |
|---|---|---|---|
| | ES-1 value | ES-2 value | ES-n value |
| Hn | VES1 | VES2 | VESn |

| Criteria to value ES-n (VESn) | |
|---|---|
| e.g. Coastal protection | |
| Perc. wave attenuation | Value |
| 67-100% | 3 |
| 34-66% | 2 |
| 1-33% | 1 |
| 0% | 0 |

| Value of Natural Values (VNV) | | | |
|---|---|---|---|
| | NV-1 value | NV-2 value | NV-n value |
| Hn | VNV1 | VNV2 | VNVn |

| Criteria to value NV-n (VNVn) | |
|---|---|
| e.g. Habitat provision | |
| Perc. of typical species | Value |
| >90% | 3 |
| 76-90% | 2 |
| 50-75% | 1 |
| <50% | 0 |

*Figure 4 Second (2nd) step of the proposed method: specification of measures by application of criteria to assess the value of an ecosystem service (VES-n) or a natural value (VNV-n).*

3. Thirdly and finally, we need to **combine or integrate the separate assessed values to arrive at an overall assessed value for each habitat type**. The intrinsic nature of natural values contrasts to the extrinsic nature of ecosystem services, which hampers straightforward integration of these two types of values. However, (monetary) valuations or ratings of each natural value and each ecosystem service can be combined to generate an overall rating for each habitat type (Figure 5).

| Ranked list | | |
|---|---|---|
| Habitat type | Value | Rank |
| H2 | V(H2) | 1 |
| Hn | V(Hn) | 2 |
| H.. | V(H..) | .. |
| H.. | V(H..) | .. |
| H1 | V(H1) | n |

| Overall value | | | |
|---|---|---|---|
| | ES value (VES) | Natural value (VNV) | Overall value (V) |
| Hn | VES | VNV | V=VES+VNV |

| Value of Ecosystem Services (VES) | | | | |
|---|---|---|---|---|
| | ES-1 value | ES-2 value | ES-n value | ES value (VES) |
| Hn | VES1 | VES2 | VESn | VES=VES1+VES2+...+VESn |

| Value of Natural Values (VNV) | | | | |
|---|---|---|---|---|
| | NV-1 value | NV-2 value | NV-n value | NV value (VNV) |
| Hn | VNV1 | VNV2 | VNVn | VNV=VNV1+VNV2+..+VNVn |

*Figure 5 Third (final) step of the proposed method: a bottom-up approach to combine and integrate assessed values of the various identified natural values and ecosystem services of several habitat types. Note: prior to combination ratings may have to be standardized.*

### 3.1.1 Inventories

The first part of the habitat ranking methodology consists of compiling three sets of inventories: of habitats, of natural values and ecosystem services, and of biophysical processes and habitat components.

*Habitats* – A list of habitats to be considered in the study needs to be compiled. This inventory is necessary to delineate the scope of the study. In the present study, we aim at ranking the various coastal habitats of the Habitats Directive that occur along the Dutch coast.

*Natural values and ecosystem services (for each habitat)* – For each listed habitat a list of potential natural values and of potential ecosystem services should be compiled. Both natural values and ecosystem services can be selected from published or otherwise available lists. For ecosystem services of coastal habitats we here use the list for marine biodiversity published by Beaumont et al. (2007; see paragraph 2.1.2). For natural values we have extracted a list of values used in the Dutch "profile documents" (Ministerie LNV, 2008; see paragraph 4.1.1) that describe and rate the state of the natural values of (coastal) habitats of the Habitats Directive.

*Biophysical processes and habitat components* – For listed natural values and ecosystem services of each habitat, a list of biophysical processes and habitat components potentially contributing to the natural value or ecosystem service should be compiled. We have not been able to find readily available lists of processes and components that contribute to the various ecosystem services. For natural values we have extracted lists of processes and components values used in the Dutch "profile documents" (Ministerie LNV, 2008; see paragraph 4.1.1) that are described to contribute mainly to the natural value "quality".

### 3.1.2 Rating

Knowing and quantitatively rating the contribution of a habitat component to a biophysical process and of a biophysical process to a natural value or ecosystem service is the groundwork on which the assessment of natural values and ecosystem services should be built. To compile an overview of all relevant components and processes is already a tedious tasks, and underpinning their contribution to biophysical processes and values or services, respectively, based on research is a vast field of research in itself. For example, ideally, we would like to know the effects of water depth, sea grass fields, salt marshes and shellfish reefs on wave dampening and accretion of sediment to assess their contribution to the ecosystem service coastal protection. Apart from the specific research that is needed to assess these (direct) contributions, indirect contributions of components or processes to a natural value or ecosystem service further complicates the assessment. For example, coral reefs attenuate waves and also create sheltered conditions suitable for growth of mangrove and sea grass, thereby contributing indirectly to coastal protection.

When using expert judgement rating, rather than quantitative or monetary valuation, it is necessary to determine what kind of scale type should be used. Because the aim of this study is to produce a ranking order of habitat types, we opt for an ordinal scale. Ordinal measurements are used to describe order, but not relative size or degree of difference between the items measured. In this scale type, the numbers assigned represent the rank order (1st, 2nd, 3rd, etc.) of the entities assessed. Thus, when we want to assess a contribution in one of four classes, such as 'marginal/absent', 'low', 'moderate' or 'high', they can be represented by the numbers 0, 1, 2 and 3.

The ordinal scale represents a qualitative assessment and is limited to ranking the various components. When a bit more detail is known or required, the original ordinal scale can be transformed to achieve semi-quantitative ranks. When the differences between the ranks are expected to be more or less similar (linear scale), the original ranks also represents the difference between the ranks. When differences between ranks are expected to be on an exponential scale, the numbers representing ranks can be transformed (e.g., $e^x$, $2^x$, or $10^x$), etc. (Table 2). In our elaboration (see Chapter 4), we opt for the basic, linear scale (0,1,2,3; see also Figure 4).

*Table 2 Rating on an ordinal scale and examples of transformations of results.*

| Rank | Linear | Exponential (2-base) | Exponential (e-base) | Exponential (10-base) |
|---|---|---|---|---|
| 0 | 0 | 1 | 1 | 1 |
| 1 | 1 | 2 | 2.7 | 10 |
| 2 | 2 | 4 | 7.4 | 100 |
| 3 | 3 | 8 | 20.1 | 100 |

### 3.1.3 Combining ratings

The simple numerical ranked (i.e., linear ordinal) scale allows fairly straightforward combination or integration of multiple ratings.

When the various habitat components and biophysical processes are rated for their contribution to a natural value or ecosystem service, the resulting numbers representing ranks have to be combined to generate a rating for each natural value or ecosystem service. When doing so, the contributions of the various components and biophysical processes have to be balanced, because each natural value or ecosystem process may be based on only one, a few or on many different habitat components or biophysical processes, which would result in low and high rating respectively. The same applies to the following level, when the ratings of natural values and ecosystems services have to be combined or integrated to yield an overall rating for the habitat. Therefore, prior to combining, the original ratings have to be standardized to the same scale, e.g., 0-1 or 0-x.

In sum, to combine the ratings, we suggest a bottom-up approach:

- Ratings for habitat components and biophysical processes are combined by natural value or ecosystem service;
- Standardizing the rating for natural values and the rating of ecosystem values, i.e., the ratings have to have the same spread. This is necessary before combining the two ratings. In our elaboration we have simply used the ranks, because both using ecosystem services and natural values the coastal habitats fell into seven ranks. Alternatively, the ratings can be converted to a fraction (values between 0 en 1).
- Ratings for separate natural values and ecosystem services are then combined to obtain an overall rating for ‘the’ natural value or ‘the’ ecosystem services of a habitat;
- The overall ratings of natural value and ecosystem services are each ranked; Note: the number of ranks and the order of ranks (‘bad’ to ‘good’ or *vice versa*) for both natural value and ecosystem services should be similar;
- Ranks of natural value and ecosystem services of a habitat are combined to obtain a total rating for each habitat;
- Total ratings of a series of habitats can be ranked.

### 3.1.4 Comparing and ranking

After listing, rating and combining the natural values and ecosystem services of a habitat, the ratings can be used for various purposes. E.g., the overall rating for each habitat can be used to compare and rank habitats, which was the incentive for this report. Other applications of the method depend on the focus or the underlying question. For example, habitats may be compared in their contribution to specific natural values (e.g., the state of the habitat quality differs between habitat types) or ecosystem services (e.g., one habitat type contributes in its currents state more to coastal protection than another habitat type) and the contribution of a habitat to a natural value or ecosystem service can be compared to its contribution to another natural value or ecosystem service (e.g., the distribution and surface are of a habitat is good, but its quality and prospects are poor; or, the production services of a habitat are fair, whereas its regulation services are average). These evaluations in words ('poor', 'good') will be supported by the (semi-quantitative) values of the ratings. Many more applications, such as assessing the effects of human activities or project, are possible.

Ranking of the coastal habitat types, the aim of this study, will be based on the total ratings of a habitat, which combines the ratings of both its natural values and its ecosystem services.

In this report, we describe a method to assess and rate the value of nature by using the value of ecosystem services and the natural values of Dutch coastal habitats. We combine these ratings to arrive at an overall ranking of the various coastal habitats. The focus of this report is on the method. The here described realized assessment, rating and ranking exemplifies the method developed, but is not completely based on objective criteria. Rather, it uses 'a' classification of ecosystem services and natural values and the rating is based on the common ecological knowledge of the authors (who are not experts on coastal habitats). The results are therefore indicative and aimed at exemplifying the developed method, rather than resulting in a definite ranking of the habitats.

# 4 Results

## 4.1 Ranking coastal habitats based on natural values

### 4.1.1 Inventories

*Habitats*

In the Dutch coastal area EU Natura 2000-habitats of the open sea and tidal areas are found, as well as salt marshes and dune habitats. A total of 14 habitat types have been defined, some of which are differentiated into several subtypes. Including subtypes, the coastal habitats comprise 26 types (see Table 3).

*Table 3 Overview of Dutch coastal habitat types*

| **Type** | **Name** | **Subtypes** | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| H1110 | Sandbanks which are slightly covered by sea water all the time | tidal zone | NS coastal zone | | |
| H1140 | Mudflats and sandflats not covered by seawater at low tide | tidal zone | NS coastal zone | | |
| H1310 | *Salicornia* and other annuals colonizing mud and sand | *Salicornia* sp. | *Sagina maritime* | | |
| H1320 | *Spartina* swards | | | | |
| H1330 | Atlantic salt meadows | outside the dykes | behind the dykes | | |
| H2110 | Embryonic shifting dunes | | | | |
| H2120 | Shifting dunes along the shoreline with *Ammophila arenaria* ('white dunes'). | | | | |
| H2130 | Fixed coastal dunes with herbaceous vegetation ('grey dunes') | rich in lime | poor in lime | poor | |
| H2140 | Decalcified fixed dunes with *Empetrum nigrum* | humid | dry | | |
| H2150 | Atlantic decalcified fixed dunes (Calluno-Ulicetea) | | | | |
| H2160 | Dunes with *Hippophae rhamnoides* | | | | |
| H2170 | Dunes with *Salix repens* spp. *argentea* (*Salicornia arenariae*) | | | | |
| H2180 | Wooded dunes of the Atlantic, Continental and Boreal region | dry | humid | inner dunes | |
| H2190 | Humid dune slacks | open water | rich in lime | decalcified | tall swamp plants |

*Natural values*

All Dutch habitats have been described in profile documents (Ministerie LNV, 2008). In these documents, following the method established in 2006 by the Habitats Committee (ex. Art. 20 of the Habitat Directive), four aspects of the national conservation status (i.e., natural values) are distinguished (derived from: EC, 2007; Ministerie LNV, 2008):

- Range (i.e., the area over which a habitat is usually to be found),
- Surface area (i.e., area covered by a habitat type within its range),
- Quality: abiotic preconditions, structure and functioning including typical species,
- Prospects.

*Biophysical processes and habitat components*

In the profile documents describing and characterizing the habitats, only the natural value *Quality* is built on underlying processes resulting from components of the habitat. To specify the value *Quality*, the following processes and components are used in the profile documents of the coastal habitats:

- Abiotic preconditions of vegetated and non-vegetated coastal habitats:

| vegetated | non-vegetated |
|---|---|
| | o water quality (chemical) |
| o humidity | o transparency |
| o salinity | o salinity |
| o nutritional state | o nutritional state |
| o tolerance to inundation | o hydro-morphological dynamics / tolerance to disturbance |

- Structure and functioning:
  - typical species
  - sediment composition
  - structures
  - composition of communities.

### 4.1.2 Rating

The four aspects or values of natural values mentioned above together determine the overall rating of a habitat type. Each of the four values is assessed and classified as either 'favourable' (represented by the colour green), 'unfavourable-inadequate' (represented by amber), 'unfavourable-bad' (represented by red) or 'unknown'. Criteria for the evaluation and assessment are given in Annex E in EC (2007). In the context of Natura 2000, the elaboration of the Habitats Directive, this overall rating is termed "conservation status" and translated into conservation objectives. The current status of a habitat is condensed into the conservation status, the actions needed to achieve potential status is condensed into the conservation objectives. Elaboration of the natural values culminating in assessment of both conservation status and objectives has been laid down in profile documents for each habitat type (Ministerie LNV, 2008).

*By natural value*

Required and current status of habitat components and biophysical processes are described in the profile documents (Ministerie LNV, 2008). These descriptions (in words) have not been condensed into a (semi-)quantitative rating of the components and processes. The information used for the descriptions is based on peer-reviewed literature and reports.

*By habitat type*

Each profile document ends with an overview of the ratings ("assessment") for each of the four aspects of natural value. The overall rating by habitat type (termed "overall assessment of conservation state" in EC, 2006) is based on the ratings of the four aspects by applying the following rules:

- Favourable: when all four aspects are rated 'favourable', or when three aspects are rated 'favourable' and one aspect 'unknown'
- Unfavourable-inadequate: when one or more aspects are rated 'unfavourable-inadequate' and no aspect is rated 'unfavourable-bad'
- Unfavourable-bad: one or more aspects are rated 'unfavourable-bad'.

We have translated the current rating in wording into a numerical rating: unfavourable-bad = 1, unfavourable-inadequate = 2 and favourable = 3. The consequent interpretation of this way of rating means that habitats that are not in a favourable state receive a low rating (value), and, when ranked, appear high in the ranked list (no. 1, 2, etc.). An overview of the Dutch coastal habitat types according to the HR and their current conservation status and objectives for each of the four natural values is given in Table 4 left panel.

*Table 4* *Overview of ratings of the four aspects of natural values of Dutch coastal habitat types, including overall rates for the total natural value of the habitats according to the method described in chapter 3. Ranking of the habitats, based on the overall rating of their natural value. Habitats with a high rank are assigned a low number.*

*Left panel*

| **Habitat type** | | **Conservation status (current)** Distribution | Surface area | Quality | Prospects | ***Overall*** |
|---|---|---|---|---|---|---|
| H1110 | A | 3 | 3 | 2 | 2 | ***10*** |
| | B | 3 | 3 | 2 | 2 | ***10*** |
| H1140 | A | 3 | 3 | 2 | 2 | ***10*** |
| | B | 3 | 3 | 3 | 3 | ***12*** |
| H1310 | A | 3 | 2 | 3 | 2 | ***10*** |
| | B | 3 | 3 | 3 | 3 | ***12*** |
| H1320 | | 3 | 3 | 1 | 1 | ***8*** |
| H1330 | A | 3 | 3 | 2 | 2 | ***10*** |
| | B | 3 | 3 | 2 | 2 | ***10*** |
| H2110 | | 3 | 3 | 3 | 3 | ***12*** |
| H2120 | | 3 | 3 | 2 | 3 | ***11*** |
| H2130 | A | 3 | 2 | 1 | 1 | ***7*** |
| | B | 3 | 2 | 1 | 1 | ***7*** |
| | C | 2 | 1 | 1 | 1 | ***5*** |
| H2140 | A | 3 | 3 | 2 | 3 | ***11*** |
| | B | 3 | 3 | 2 | 3 | ***11*** |
| H2150 | | 3 | 3 | 3 | 3 | ***12*** |
| H2160 | | 3 | 3 | 3 | 2 | ***11*** |
| H2170 | | 3 | 3 | 3 | 3 | ***12*** |
| H2180 | A | 3 | 3 | 3 | 3 | ***12*** |
| | B | 3 | 3 | 2 | 3 | ***11*** |
| | C | 3 | 3 | 2 | 3 | ***11*** |
| H2190 | A | 3 | 3 | 2 | 3 | ***11*** |
| | B | 3 | 2 | 2 | 2 | ***9*** |
| | C | 3 | 2 | 2 | 3 | ***10*** |
| | D | 2 | 2 | 3 | 3 | ***10*** |

*Right panel*

| **Ranking** Habitat type | | Rate | Rank |
|---|---|---|---|
| H2180 | A | 12 | 1 |
| H2170 | | 12 | 1 |
| H2150 | | 12 | 1 |
| H2110 | | 12 | 1 |
| H1310 | B | 12 | 1 |
| H1140 | B | 12 | 1 |
| H2190 | A | 11 | 2 |
| H2180 | B | 11 | 2 |
| H2180 | C | 11 | 2 |
| H2160 | | 11 | 2 |
| H2140 | A | 11 | 2 |
| H2140 | B | 11 | 2 |
| H2120 | | 11 | 2 |
| H2190 | C | 10 | 3 |
| H2190 | D | 10 | 3 |
| H1330 | A | 10 | 3 |
| H1330 | B | 10 | 3 |
| H1310 | A | 10 | 3 |
| H1140 | A | 10 | 3 |
| H1110 | A | 10 | 3 |
| H1110 | B | 10 | 3 |
| H2190 | B | 9 | 4 |
| H1320 | | 8 | 5 |
| H2130 | A | 7 | 6 |
| H2130 | B | 7 | 6 |
| H2130 | C | 5 | 7 |

Legend: Conservation status
3 = favourable (green)
2 = unfavourable-inadequate (orange)
1 = unfavourable-bad (red)

### 4.1.3 Ranking based on natural values

The overall rating for natural value of each coastal habitat (last column of left panel of Table 4) is used to rank these habitats (Table 4, right panel). The larger part of the habitats fall into three ranks (1, 2, 3) only. The rating of the natural values of the habitats varies across each of the three groups of habitats, open seas, tidal water and sea dunes.

## 4.2 Ranking coastal habitats based on ecosystem services

### 4.2.1 Inventories

*Habitats*

When determining the ecosystem services value for the Dutch coastline, the same habitat types apply as in assessing the nature value. See Table 3, paragraph 4.1.1., for an inventory of habitats.

*Ecosystem services*

As mentioned before (paragraph 2.1.2), multiple lists of ecosystem services have been developed (Costanza et al., 1997; De Groot et al., 2002; MEA, 2003; Wallace, 2007; Boyd & Banzhaf, 2007; Fisher & Turner, 2008; Beaumont et al., 2007; Salomidi et al., 2012). There is debate about which classification of ecosystem services is best to use when developing a framework for guiding practical accounting exercises or landscape management (Boyd & Banzhaf, 2007; Wallace, 2007; Fisher & Turner, 2008). Here we opted for an adjusted version of the MEA-classification by Beaumont et al. (2007), that applies to a marine environment (Table 5). Beaumont et al. (2007) added the option use value proposed by Hein et al. (2006), which represents the service of future unknown and speculative benefits. It is associated with the willingness to pay to ensure the option to use a service in the future, when such use is currently not planned.

Table 5 *A list of ecosystem services: goods and services provided by a marine environment and divided into five categories (adapted from Beaumont et al., 2007). The classification of ecosystem services applied here follows the Millennium Ecosystem Assessment (2003) and the proposed addition by Hein et al., (2006). Goods and services are defined as 'the direct and indirect benefits people obtain from ecosystems'.*

| **Category** | **Ecosystem service (good or service)** |
|---|---|
| Production services | 1. Food provision<br>2. Raw materials |
| Regulation services | 3. Gas and climate regulation<br>4. Disturbance prevention (flood and storm protection)<br>5. Bioremediation of waste |
| Cultural services | *6. Cultural heritage and identity*<br>7. Cognitive benefits<br>8. Leisure and recreation<br>*9. Feel good or warm glow (non-use benefits)* |
| Option use value | *10. Future unknown and speculative benefits* |
| Over-arching support services | *11. Resilience and resistance (life support)*<br>*12. Biologically mediated habitat*<br>*13. Nutrient cycling* |

While rating the ecosystem services, it appeared that several ecosystem services are nearly impossible to assess, such as cultural heritage identity, feel good or warm glow and future unknown and speculative benefits (printed in italics in Table 5). These three categories of ecosystem services represent highly subjective experiences. Rating these services in a more objective way requires e.g., a population survey. Therefore, these services were not included in the present elaboration of the method.

In our opinion, the overarching services represent the underlying natural values (see paragraph 2.1.1) and therefore, we do not include them in the present elaboration of the ecosystem services. They are inclusive in the assessment of the (intrinsic) natural values (paragraph 4.1).

*Biophysical processes and habitat components*
The inventory of the biological, chemical and physical processes and of the habitat components that contribute to the various ecosystem services are far from readily available. It would require an extensive literature study to get an overview of what is and what is not known. This was not possible during this study. We therefore did not include these processes and components.

### 4.2.2 Rating

Ideally, the selection and rating of ecosystem services should be based on a criterion-based rating of the biophysical processes and habitat components contributing to the final ecosystem services and the benefits the habitat provides society (Fisher & Turner, 2008; see also paragraph 3.1.2). In the absence of published knowledge, needed to select and rate ecosystem services and their contributing biophysical processes and habitat components, we resorted to a shortened and simplified version of the method based on common ecological knowledge of the authors (a simplified version of 'expert judgement'). Rating based on expert judgement results in a subjective rating, whereas criterion-based rating of the contribution of underlying processes and components to the ecosystem services represents a more objective and transparent method. However, expert-judgement rating can be underpinned with measures: clarification of the choice upon which the rating is given (see Figure 4).

In our expert judgement, each ecosystem service has been assigned a numerical score on an ordinal scale, based on the perceived potential of the habitat type to provide this ecosystem service. In case an ecosystem service has several components, individual rating of the components provide insight in which of these contribute to the total value of the ecosystem service and how. The ratings are assembled in tables. The table compacted at the level of ecosystem category is presented in Table 6, left panel. The full table for all coastal habitats (including subtypes) and rated individual ecosystem services is given in Annex 1.

*Table 6 Overview of averaged ratings (by authors) of provision of coastal habitats to categories of ecosystem services, including overall rate (summed rate of the three categories production, regulation and cultural services) for the total ecosystem services of the habitats according to the method described in chapter 3. Ranking of the habitats, based on their ecosystem services. Habitats with many ecosystem services are given a high rank (i.e. a low number).*

| **Habitat type** | | **Ecosystem service categories** | | | |
|---|---|---|---|---|---|
| | | Production | Regulation | Cultural | ***Overall*** |
| H1110 | A | 1.1 | 1.3 | 1.9 | ***4.3*** |
| | B | 1.1 | 1.3 | 1.9 | ***4.3*** |
| H1140 | A | 1.0 | 1.3 | 2.0 | ***4.3*** |
| | B | 1.0 | 1.3 | 2.0 | ***4.3*** |
| H1310 | A | 0.1 | 1.7 | 1.9 | ***3.8*** |
| | B | 0.1 | 1.7 | 1.9 | ***3.7*** |
| H1320 | | 0.1 | 1.7 | 1.9 | ***3.7*** |
| H1330 | A | 0.3 | 1.7 | 1.9 | ***3.9*** |
| | B | 0.3 | 1.7 | 1.9 | ***3.9*** |
| H2110 | | 0.2 | 0.8 | 1.9 | ***2.9*** |
| H2120 | | 0.2 | 1.2 | 1.9 | ***3.2*** |
| H2130 | A | 0.5 | 1.3 | 1.9 | ***3.7*** |
| | B | 0.5 | 1.3 | 1.9 | ***3.7*** |
| | C | 0.6 | 1.3 | 1.9 | ***3.8*** |
| H2140 | A | 0.5 | 1.3 | 1.8 | ***3.6*** |
| | B | 0.5 | 1.3 | 1.8 | ***3.6*** |

| **Ranking** | | | |
|---|---|---|---|
| Habitat type | | Rating | Rank |
| H1110 | A | 4.3 | 1 |
| H1110 | B | 4.3 | 1 |
| H1140 | A | 4.3 | 1 |
| H1140 | B | 4.3 | 1 |
| H1330 | A | 3.9 | 2 |
| H1330 | B | 3.9 | 2 |
| H1310 | A | 3.8 | 3 |
| H2130 | C | 3.8 | 3 |
| H2160 | | 3.8 | 3 |
| H1310 | B | 3.7 | 4 |
| H1320 | | 3.7 | 4 |
| H2150 | | 3.7 | 4 |
| H2130 | A | 3.7 | 4 |
| H2130 | B | 3.7 | 4 |
| H2140 | A | 3.6 | 5 |
| H2140 | B | 3.6 | 5 |

| Habitat type | | Ecosystem service categories Production | Regulation | Cultural | Overall |
|---|---|---|---|---|---|
| H2150 | | 0.6 | 1.3 | 1.8 | ***3.7*** |
| H2160 | | 0.5 | 1.5 | 1.8 | ***3.8*** |
| H2170 | | 0.5 | 1.3 | 1.8 | ***3.6*** |
| H2180 | A | 0.3 | 1.5 | 1.8 | ***3.6*** |
| | B | 0.3 | 1.5 | 1.8 | ***3.6*** |
| | C | 0.3 | 1.5 | 1.8 | ***3.6*** |
| H2190 | A | 0.2 | 1.0 | 2.0 | ***3.2*** |
| | B | 0.2 | 1.0 | 2.0 | ***3.2*** |
| | C | 0.2 | 1.0 | 1.9 | ***3.2*** |
| | D | 0.2 | 1.0 | 1.9 | ***3.2*** |

Legend: 0 = marginal or absent (0-0.5); 1 = low (0.5-1.5); 2 = moderate (1.5-2.5); 3 = high (2.5-3)

| Ranking Habitat type | | Rating | Rank |
|---|---|---|---|
| H2170 | | 3.6 | 5 |
| H2180 | A | 3.6 | 5 |
| H2180 | B | 3.6 | 5 |
| H2180 | C | 3.6 | 5 |
| H2120 | | 3.2 | 6 |
| H2190 | A | 3.2 | 6 |
| H2190 | B | 3.2 | 6 |
| H2190 | C | 3.2 | 6 |
| H2190 | D | 3.2 | 6 |
| H2110 | | 2.9 | 7 |

### 4.2.3 Ranking based on ecosystem services

The overall rate for the ecosystem services of each coastal habitat (see Table 6, last column of right panel) is used to make a ranking of these habitats. Based on the rating by the authors, it appears that dune habitats provide fewer ecosystem services than saltmarshes and tidal areas. Open sea habitat provides the most ecosystem services of the coastal habitats according to the current rating.

## 4.3 Ranking of coastal habitats based on natural values and ecosystem services combined

The ranking of the coastal habitats based on their natural values (Table 4) and based on their ecosystem services (Table 6) are combined to generate and overall ranking based on both types of values. To do so, we assumed equal weight of natural values and ecosystem services and simply averaged the ranks (1-7) based on the separated values, re-ordered them and assigned new ranks (Table 7).

This ranking allows a first, general evaluation of the effects of a project (an intervention) with the most simplest of effects: it reduces the area of one habitat type, while facilitating the development of another habitat type. If the newly developing surface area is of a habitat type with higher ranking than the habitat type that will be reduced, the simplest answer will be that, given the correctness of the assessment, the project would enhance the overall value of the area (its surroundings where the effects occur). If the newly developing area is of a lower ranked habitat type than the reduced area, the project would reduce the overall value of the area. For example, if surface area of submerged habitats (H11xx, ranks 1 and 2) is used to enable the new development of tidal flats, marshes (H13xx, rank 3) or embryonic dunes (H2110, rank 6), a concept similar to the ‘sand motor’ (Zandmotor, see: www.thezandmotor.nl, in Dutch), the overall value of this coastal area is likely enhanced. Submerged habitats (H11xx) in our limited assessment have the highest overall rank, due to the high rating of ecosystem services provided by these habitats. Based on natural values only, submerged and marsh habitats have a similar rank. Exchanging some submerged habitat for newly developing marsh habitat thus increases the value of nature as assessed by its ecosystem services. When this can be achieved without negative effects on the assessed rank of the submerged habitats based on its natural values – a (small) reduction in surface may represent a minor effect only – the overall natural value (according to our rating) of the area will increase.

*Table 7* *Overview of ranks of coastal habitats based on natural values and on ecosystem services (left panel), and ranks based on both types of values combined (right panel).*

| **Habitat type** | | **Specific rank** | | **Combined rank** |
|---|---|---|---|---|
| | | Natural value | Ecosystem services | (average) |
| H1110 | A | 3 | 1 | 2 |
| | B | 3 | 1 | 2 |
| H1140 | A | 3 | 1 | 2 |
| | B | 1 | 1 | 1 |
| H1310 | A | 3 | 3 | 3 |
| | B | 1 | 4 | 2,5 |
| H1320 | | 5 | 4 | 4,5 |
| H1330 | A | 3 | 2 | 2,5 |
| | B | 3 | 2 | 2,5 |
| H2110 | | 1 | 7 | 4 |
| H2120 | | 2 | 6 | 4 |
| H2130 | A | 6 | 4 | 5 |
| | B | 6 | 4 | 5 |
| | C | 7 | 3 | 5 |
| H2140 | A | 2 | 5 | 3,5 |
| | B | 2 | 5 | 3,5 |
| H2150 | | 1 | 4 | 2,5 |
| H2160 | | 2 | 3 | 2,5 |
| H2170 | | 1 | 5 | 3 |
| H2180 | A | 1 | 5 | 3 |
| | B | 2 | 5 | 3,5 |
| | C | 2 | 5 | 3,5 |
| H2190 | A | 2 | 6 | 4 |
| | B | 4 | 6 | 5 |
| | C | 3 | 6 | 4,5 |
| | D | 3 | 6 | 4,5 |

| **Habitat type** | | **New rank** |
|---|---|---|
| H1140 | B | 1 |
| H1110 | A | 2 |
| H1110 | B | 2 |
| H1140 | A | 2 |
| H1310 | B | 3 |
| H1330 | A | 3 |
| H1330 | B | 3 |
| H2150 | | 3 |
| H2160 | | 3 |
| H1310 | A | 4 |
| H2170 | | 4 |
| H2180 | A | 4 |
| H2140 | A | 5 |
| H2140 | B | 5 |
| H2180 | B | 5 |
| H2180 | C | 5 |
| H2110 | | 6 |
| H2120 | | 6 |
| H2190 | A | 6 |
| H1320 | | 7 |
| H2190 | C | 7 |
| H2190 | D | 7 |
| H2130 | A | 8 |
| H2130 | B | 8 |
| H2130 | C | 8 |
| H2190 | B | 8 |

The ranking should be applied as a first evaluation only, because local circumstances, such as whether or not Natura 2000-areas are affected and local potential of the various underlying values (both natural values and ecosystem services) may affect their rating and thus the ranking of the habitats.

# 5 Discussion

The main aim of the present study is to develop a ranked list of Dutch coastal habitat types based on their ecosystem services. The idea is that a ranked list may facilitate the (first steps in) decision processes, for example, when planning infrastructural projects concerning the coast. Such a ranked list allows assessing whether the overall value of the area may increase, decreases or remain the same when one habitat type (surface area or quality aspects) is exchanged for another. The underlying derivation of the ranking, based on inventory and valuation of the ecosystem services of the habitats, provides further insight into which ecosystem services are decreased or lost and increased or gained as a result of a planned project.

*Extrinsic and intrinsic value of nature: ecosystem services and natural values*
To use “ecosystem services” for ranking coastal habitats, we needed a consistent definition of this concept and a comprehensible list. However, the development and evolution of the concept of ecosystem services has been a long process, resulting in a plethora of alternative definitions and classifications. And at present there is still no consistent definition and classification of ecosystem services. We have adopted the point of view of Fisher et al. (2009) that ecosystem services are those aspects of the ecosystem that can be used by humans. This implies that the ecosystem services approach to valuing nature limits nature to its extrinsic value, i.e., those aspects that can or may be used by humans, and neglects the intrinsic value of nature. When defining ecosystem services, many authors try to capture the intrinsic value by labelling it in accordance with a (potential) use by humans, e.g., supporting or habitat services or option use value. In this way, (intrinsic) natural values are viewed as a subset of ecosystem services, which is somewhat opposite to the view of Fisher et al. (2009). A large part of the Dutch coastal habitats is designated Natura 2000-area, which means that these habitats are valued and protected owing to their (intrinsic) natural values only. We therefore decided to make an explicit distinction between the human use of nature, represented by ecosystem services and constituting the extrinsic value of nature, and the ecosystem components and processes, constituting the intrinsic value of nature or natural value. Extrinsic and intrinsic valuation of nature are based on different motivations and may therefore result in different values that will be attached to habitats. This point of view and our approach developed here to attach separate and integrated values (and ranks) to coastal habitats based on extrinsic and intrinsic valuation gives a more complete picture of the value of nature than based on ecosystem services only. This approach also allows development of custom-made options and choices for managers and other decision makers.

*Criterion-based versus expert-judgement assessment*
To determine which ecosystem services and natural values a habitat type may potentially provide, these are ideally derived from the natural components of a habitat and the biological, chemical and physical processes that occur within the habitat type. Such information is far from readily available and requires extensive (desk)studies and/or reviews with this aim as a focal point. Collecting, aggregating and organizing the vast amount of information on habitat components and processes and determining their individual contribution to ecosystem services will form a much needed basis in valuing natural habitats.
In addition, to apply the ranking method approach in an objective way, criteria should be defined that determine the extent of the contribution of ecosystem components and processes to ecosystem services. For example, the contribution of a specific recreational activity, e.g., sailing, to the ecosystem service ‘Leisure and recreation’ can be based on the number of people that practice sailing annually within the habitat type, or on the average number of sailing boats that are present in the habitat on an annual basis. Determining and applying criteria makes the rating used in the proposed approach to rank habitats transparent and also allows for new input or insights (determining the criteria) and evaluation (assessing whether the criteria have been applied adequately).

Such a criterion-based rating system based on a clear overview of habitat components and processes and allowing objective and transparent rating of the ecosystem services of a habitat assists in foreseeing risks and possibilities that may result from infrastructural projects and conservation measures. Owing to the above mentioned lack of readily available information and appropriate reviews, in the current application of the method of assessing and rating ecosystem services of habitats described here, we resorted to published lists of ecosystem services only and based the assessment of their presence and value ("rating") on expert judgement. The intrinsic natural values of nature comprise consistent physical aspects of the ecosystem, and the easily-grasped concept of production services among the extrinsic ecosystem services are directly derived from the intrinsic natural values and their assessment appears fairly straightforward. However, the concept of cultural or information services is more elusive and their value is more susceptible to subjectivity or bias when using expert judgement. Applying the arguments of Fisher & Turner (2009), who define ecosystem services as ecological in nature, the cultural or information services are not viewed as ecosystem services but defined as benefits. Based on this, their elusiveness and difficulty to rate somewhat objectively, we excluded the cultural and information services (or benefits) from our assessment and ranking method. In view of the aforementioned considerations, the here reported assessment, rating and ranking of ecosystem services of Dutch coastal habitat is not based on objective criteria, but uses 'a' classification of ecosystem services and the rating is based on the common ecological knowledge of the authors (who are not experts on coastal habitats). The results are therefore indicative and aimed at explicate the method, rather than resulting in a definite ranking of the habitats.

Another aspect that needs further investigation is the ecosystem service list and classification that is used in this ranking method. Wallace (2007) and Fisher (2003) argue that in most classification lists processes that contribute to the realisation of end-products (i.e., benefits usable to society) and the end-products themselves are often found within the same category. This results in double-counting, that needs to be avoided to arrive at objective rating and ranking. Following the argumentation of Fisher et al. (2009), the classification of ecosystem services as developed by MEA (2003) and elaborated by Beaumont et al. (2007), which we use in this study, runs the risk of double-counting. Hein et al. (2006), Boyd & Banzhaf (2007), Wallace (2007) and Fisher & Turner (2008) all have proposed possible alternatives. They all distinguish (supporting, intermediate or final) services from benefits, which are the elements that specifically (and only) enjoyed, consumed, or used by humans. And only these benefits are valued. Hein et al. (2006) add this focus on human use the services that have an impact outside the ecosystem to be valued. The choice for the adjusted classification list of Beaumont et al. (2007) is therefore debatable. Nevertheless, as the present study focusses on conceptualising a (in principle transparent) method to rank habitats based on their ecosystem services and natural values, we decided to proceed with this classification list, allowing us to develop the principles of the rating process in the absence of the preferred, but not readily available ecosystem overview. In addition, this list concerns ecosystem goods and services provided by marine biodiversity, whereas most other classifications concern terrestrial biodiversity.

The current approach has limited discriminatory ability, owing to the applied habitat type-based (and not subtype-based) expert judgement rating and to the fact that natural values are combined and rated into four categories only. By applying knowledge and criterion-based rating applied to subtypes, most likely further differentiation will be achieved. In the current elaboration of the method, natural values and ecosystem services (i.e., all ecosystem services and categories) have been given equal weight. This choice influences the results of the ranking of coastal habitats. When a specific ecosystem service requires special attention or needs to be enhanced or reduced within an area, e.g., natural values in a Natura 2000-area or wave attenuation in a situation in which coastal protection needs to be improved, an *a posteriori* weighing factor can be implemented to emphasize relevant aspects. This will assist in identifying those habitat types that contribute substantially to enhancing or reducing this focal ecosystem service. This *a posteriori* weighing is determined by the management and policy context and should remain separate from the rating and ranking of the habitats based on scientific knowledge.

The actual state of a habitat type, i.e., which ecosystem services are actually provided and to what extent, is dependent on the specific conditions found at each location of a habitat type, and thus location specific. When rating natural values and ecosystem services, one can choose to rate the potential of each of these items in the habitat or one can choose to rate the realized or current state of these items in the habitat. The choice is dependent on the aim of the study. For our aim, a general ranking of coastal habitat types, we used the current conservation state (based on LNV, 2008) and current human use (based on our expert judgement). The present study is based on general information of habitat types and the ecosystem services that are potentially provided by the habitat types. For practical and more specific application, however, the local situation needs to be taken into account. The local situation comprises several aspects. The ‘landscape context’ refers to interference by anthropogenic factors such as (limited) accessibility or (lack of) interest, which may prohibit the actual use of the available ecosystem services by society, or factors that influence the expression of a natural value of the habitat (King, 1997). For example, the presence of e.g., (petro-)chemical industry may prohibit fishing, recreation or reproduction of sea mammals, due to pollution and disturbance resulting from of noise. The ‘habitat status’ refers to the local abiotic conditions of the habitat. For example, components or processes that are usually expected within a habitat may be absent, owing to the absence of abiotic conditions needed for these components to develop or due to anthropogenic or natural disturbances of the abiotic conditions. And finally, ‘boundary conditions’ exist, because the various ecosystem services are not independent; some are dependent on each other, whereas others cannot coexist (e.g., refuge habitat and some ways of recreation). To improve an ecosystem service within an area, these boundary conditions as well as the habitat status and the landscape context that are required for the ecosystem services to be realised have to be present in that area. Local application of our approach therefore requires an inventory of these aspects that are needed to realise the potential ecosystem services of the local habitats.

*Legal context Natura 2000*

The proposed method was elaborated to investigate the possibilities of obtaining a clear and transparent overview of ecosystem services and natural values to incorporate in a cost-benefit analysis. The methodology provides insight on the gain or loss of ecosystem services and nature value when one habitat is exchanged for another and is therefore applicable in e.g., hydraulic engineering infrastructural projects. However, an intended activity in or nearby (and with effects on) a Natura 2000-area that may result in an increase in natural value will most likely clash with Dutch nature legislation when existing natural values are negatively affected. For intended activities in or nearby (and with effects on) a Natura 2000-area the Nature Conservation Act (NCAct) requires a license and – to obtain a license – an assessment of the effects of the activity on the conservation objectives set for the affected Natura 2000-site. If the activity includes loss of surface of a protected habitat type, chances are that the effects of the activity will be judged negatively (“significant consequences”), whereas, in general, positive effects are not considered in an assessment in the context of an NCAct license. Exceptions are the ‘in favour of’ definitions, that are sometimes included in the Designation Order of a Natura 2000-site. This concept means that a specified protected habitat type may decrease to some extent, in favour of a (or several) specified other protected habitat types in the same area that are under pressure.

Baptist et al. (2012) argued that there is room for a more loose interpretation of existing Dutch legislation and they explored the options for the development of marshes in the Wadden Sea at the expense of substantial surface areas of intertidal habitats or permanently submerged sandbanks. They cite Mendelts & Boerema (2011), who refer to the ecosystem approach, in which initiatives are judged on their total, thus negative and positive effects on the entire ecosystem. This approach allows indemnifying negative effects on one habitat type by (more highly valued) positive effects on another habitat type and thereby optimising the overall natural value of a protected area or site after construction works. It is as yet unclear whether this line of argumentation will be accepted under current Dutch (and European) law.

In this report we ranked natural habitats based on an assessment of their value in terms of provisioning of ecosystem services and natural values. The ranking resulting from rating only the natural values differed from the ranking based on only ecosystem services. Combining the two types of valuing of nature resulted in an intermediate ranking. Using both types of valuing adds discriminatory power – sometimes an activity may hardly affect the natural values of an area whereas it may clearly increase (or decrease) the potential human use as represented by ecosystem services of the area. Or the other way around. The overall ranking, whether based on combined or separate values, gives a first impression of potential to increase the value of nature of an area. The separate ranking and underlying assessment allows specification of which values and to what extent may change (due to an activity). Both the ranking and the assessment therefor provide a sound and transparent basis for informed decisions.

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# Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

# Justification

Rapport C159/12
Project Number: 430.61110.75

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of a department of IMARES.

Approved: drs. J.E. Tamis
scientist

Signature:

Date: 21 December 2012

Approved: drs. F.C. Groenendijk
head of Department

Signature:

Date: 21 December 2012

# Annex 1. Overview of ratings of ecosystem services of coastal habitats

| | H1110 A | H1110 B | H1140 A | H1140 B | H1310 A | H1310 B | H1320 | H1330 A | H1330 B | H2110 | H2120 | H2130 A | H2130 B | H2130 C | H2140 A | H2140 B | H2150 | H2160 | H2170 | H2180 A | H2180 B | H2180 C | H2190 A | H2190 B | H2190 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Overall rating** | **4.3** | **4.3** | **4.3** | **4.3** | **3.8** | **3.7** | **3.7** | **3.9** | **3.9** | **2.9** | **3.2** | **3.7** | **3.7** | **3.8** | **3.6** | **3.6** | **3.7** | **3.8** | **3.6** | **3.6** | **3.6** | **3.6** | **3.2** | **3.2** | **3.2** |
| **Production services** | **1.1** | **1.1** | **1.0** | **1.0** | **0.1** | **0.1** | **0.1** | **0.3** | **0.3** | **0.2** | **0.2** | **0.5** | **0.5** | **0.6** | **0.5** | **0.5** | **0.6** | **0.5** | **0.5** | **0.3** | **0.3** | **0.3** | **0.2** | **0.2** | **0.2** |
| **Food provision** | **1.1** | **1.1** | **1.0** | **1.0** | **0.1** | **0.0** | **0.0** | **0.1** | **0.0** | **0.0** | **0.0** | **0.4** | **0.4** | **0.5** | **0.5** | **0.5** | **0.6** | **0.6** | **0.5** | **0.1** | **0.1** | **0.1** | **0.1** | **0.1** | **0.1** |
| fish | 3 | 3 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| molluscs | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| seaweed | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| crustaceans | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| fruit & seeds (nuts. berries) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| edible halophytes | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| mammals | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| fresh water | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Raw materials** | **1.0** | **1.0** | **1.0** | **1.0** | **0.2** | **0.2** | **0.2** | **0.5** | **0.5** | **0.3** | **0.3** | **0.7** | **0.7** | **0.7** | **0.5** | **0.5** | **0.5** | **0.3** | **0.5** | **0.5** | **0.5** | **0.5** | **0.3** | **0.3** | **0.3** |
| fuel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| sediment | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| grasses | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| shells | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| fish meal | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| grazing | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 1 | 0 | 0 | 0 |
| **Regulation services** | **1.3** | **1.3** | **1.3** | **1.3** | **1.7** | **1.7** | **1.7** | **1.7** | **1.7** | **0.8** | **1.2** | **1.3** | **1.3** | **1.3** | **1.3** | **1.3** | **1.3** | **1.5** | **1.3** | **1.5** | **1.5** | **1.5** | **1.0** | **1.0** | **1.0** |
| **Gas and climate regulation** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **0.5** | **0.5** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.0** | **1.5** | **1.0** | **1.5** | **1.5** | **1.5** | **1.0** | **1.0** | **1.0** |
| $CO_2$-sequestration | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 |
| N-sequestration | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| | H1110 A | H1110 B | H1140 A | H1140 B | H1310 A | H1310 B | H1320 | H1330 A | H1330 B | H2110 | H2120 | H2130 A | H2130 B | H2130 C | H2140 A | H2140 B | H2150 | H2160 | H2170 | H2180 A | H2180 B | H2180 C | H2190 A | H2190 B | H2190 C |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Disturbance prevention (flood and storm protection)** | **1** | **1** | **1** | **1** | **2** | **2** | **2** | **2** | **2** | **2** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **0** | **0** | **0** |
| vegetation | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Lanice conchilega* | | | | | | | | | | | | | | | | | | | | | | | | | |
| shellfish reefs | | | | | | | | | | | | | | | | | | | | | | | | | |
| elevated state (dunes) | | | | | | | | | | | | | | | | | | | | | | | | | |
| sand banks | | | | | | | | | | | | | | | | | | | | | | | | | |
| sediment retention | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Bioremediation of waste** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **2** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **0** | **2** | **2** | **2** |
| bioturbation. burial | | | | | | | | | | | | | | | | | | | | | | | | | |
| filtration | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Cultural services** | **1.9** | **1.9** | **2.0** | **2.0** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.9** | **1.8** | **1.8** | **1.8** | **1.8** | **1.8** | **1.8** | **1.8** | **1.8** | **2.0** | **2.0** | **1.9** |
| **Cognitive benefits** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** | **3** |
| research | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| education | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Leisure and recreation** | **0.9** | **0.9** | **1.0** | **1.0** | **0.9** | **0.9** | **0.9** | **0.9** | **0.9** | **0.8** | **0.8** | **0.8** | **0.8** | **0.8** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **0.6** | **1.0** | **1.0** | **0.9** |
| swimming | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| beach recreation | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 |
| walking | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| surfing | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| wildlife watching | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| sailing. jetski | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| angling | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| food foraging | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Legend: 0 = marginal or absent; 1 = low; 2 = moderate; 3 = high