Natural capital accounts for the North Sea: The physical SEEA EEA accounts Final report

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1. Introduction

Natural capital accounting (ecosystem accounting) is a statistical approach to systematically measure and monitor ecosystem services and ecosystem condition over time for decision making and planning. Under the auspices of the United Nations, the System of Environmental Economic Accounting – Experimental Ecosystem Accounting (SEEA EEA) has been developed to guide the implementation of ecosystem accounting (UN et al., 2014a; 2018). Key objectives of the SEEA EEA are to measure ecosystem condition and ecosystem services in a way that is aligned with the System of National Accounting (SNA)[1] (see also textbox below).

Nationally and internationally there is much interest to test and implement natural capital accounts. More than 25 countries are developing SEEA ecosystem accounts, including large countries like Brazil, India, China and Mexico. Also in Europe there is increasing interest in these accounts. Focus thus far has been on the terrestrial environment and there is still little experience with the marine environment. There have been only a few studies applying ecosystem accounting to coastal and marine areas (ABS, 2015 and 2017; Dvarkas, 2018; EPAresearch, 2018; ONS, 2019, in prep). In June 2018, an Asia and the Pacific Regional Expert Workshop on Ocean Accounts was organised, specifically dedicated to natural capital accounting for the marine environment (ESCAP, 2018). The importance of accounting for marine areas is well recognised and further research is underway (UN et al., 2018, SEEA EEA technical recommendations; ESCAP, 2018). Marine ecosystem accounting is also one of the cross cutting issues for the SEEA EEA revision process[2].

In the Netherlands work is ongoing to test and implement SEEA ecosystem accounting. In 2016 Statistics Netherlands and Wageningen University started to work on a four year project 'Natural capital accounts for the Netherlands' funded by Ministry of Agriculture, Nature and Food Quality, as well as the Ministry of Infrastructure and Water Management and the Ministry of Economic Affairs and Climate of the Netherlands. The choice was made to develop the SEEA EEA core accounts and thematic account for carbon and biodiversity, but to focus on the terrestrial environment. All these accounts have now been developed and will be updated and improved in 2019 and 2020.

In 2017, Statistics Netherlands did a short feasibility study, commissioned by the ministry of Infrastructure and Water Management, to examine whether and how natural capital accounts could be compiled and implemented for the Dutch continental shelf (DCS) (Statistics Netherlands, 2017a). The current project, again commissioned by Dutch Ministry for Infrastructure and Water Management in the context of the EU Marine Strategy Framework Directive, builds on the findings of this previous study. The objective of this pilot project is to test the compilation of the physical SEEA EEA accounts for the Dutch part of the North Sea, namely a) the extent account, b) the condition account, and c) the physical supply and use tables for ecosystem services[3] (see Figure 1.1). An ecosystem type map was developed as a key component of these accounts. The compilation of the accounts was done based on readily available data sources both from Statistics Netherlands and from external data sources.

[1] The System of National Accounts (SNA) is the internationally agreed standard set of recommendations on how to compile measures of economic activity. Worldwide, the SNA forms the basis for national accounts statistics and is used to calculate macroeconomic indicators such as gross domestic product (GDP) in a consistent manner.

[2] https://seea.un.org/events/2019-forum-experts-seea-experimental-ecosystem-accounting

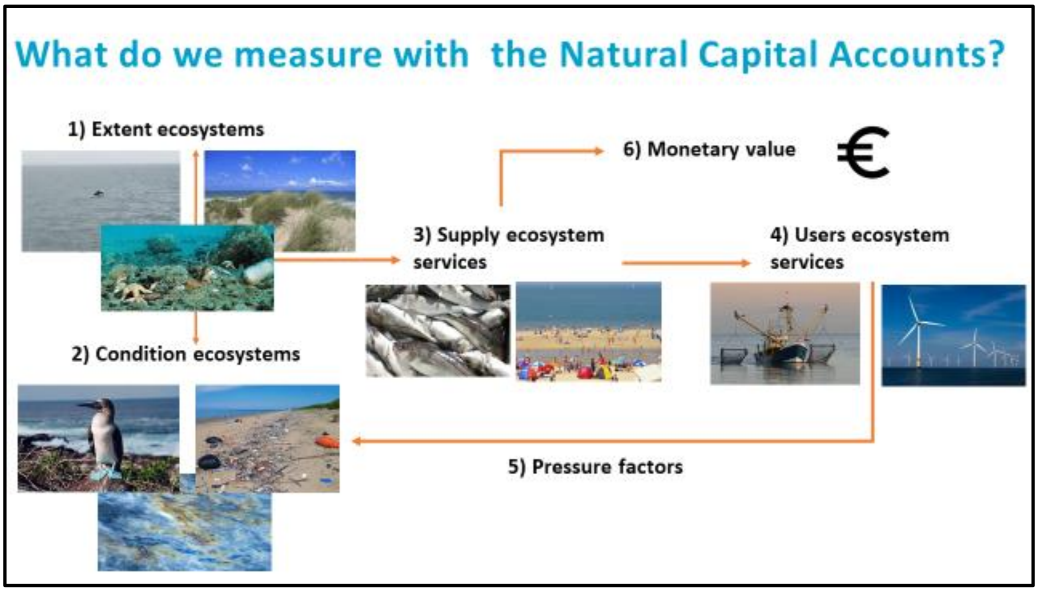
[3] The monetary SEEA EEA accounts will thus not be developed as part of this project.

Textbox: The value added of the natural capital accounts

This textbox summarizes the value added and the most important advantages of the Natural Capital Accounts.

- First of all, it is a unified and system-level approach, integrating information on separate domains (geophysics, ecology, socio-economy) such that tradeoffs and options for synergy can readily be identified and quantified.
- It is a unified, comparable international system. This means, that figures of different countries are compiled using the same methodology and, as a result, can be compared to each other.
- The system combines all relevant data (physical and monetary accounts) and there is a direct link to the economy (national accounts).
- The data of the accounts are spatially explicit, which makes them suitable for map making and consistent with other statistics and data sources. This provides a good basis for monitoring, spatial analysis, input for policy making and calculation of future scenarios.

Figure 1.1 The different parts of the Natural Capital Accounts

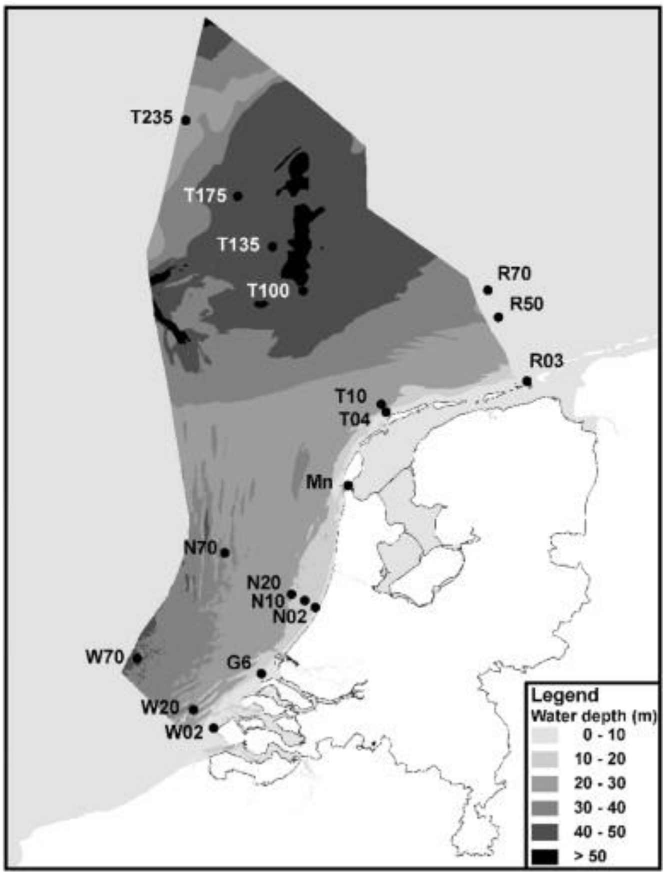


Geographical boundaries

Ecosystem accounting considers the ecosystem extent, the ecosystem conditions and ecosystem services of a specific geographic area. The geographical focus for this study is the Dutch part of the North Sea, i.e. the Dutch part of the Continental Shelf (DCS). The Dutch part of the continental shelf corresponds with the so-called Exclusive Economic Zone (EEZ) of the Netherlands, i.e. the area extending up to 200 nautical miles from a country's normal baselines as defined in the United Nations Convention on the Law of the Sea of 10 December 1982 (see figure 1.2). In the remainder of this report we will refer to the Dutch Continental Shelf (DSC) or the Dutch part of the norths Sea as the geographical scope of this study.

There are some specific geographical boundary issues that need to be addressed. It was decided to include the Wadden Sea up till the Afsluitdijk, although this area is covered by the Water Framework Directive (WFD) and not by the Marine Strategy Framework Directive (MSFD). From an ecological perspective, the ecosystem of the Wadden Sea clearly belongs to the marine realm[4]. In addition, the inclusion of the Wadden Sea is necessary in order to align with the project 'de Natuurlijk Kapitaalrekeningen voor Nederland' (the Dutch Natural Capital Accounts). After consultation with the advisory group, it was decided to also include the Westerscheldt and Oosterscheldt estuaries located in the Southwest of the Netherlands in the marine natural capital accounts.

Figure 1.2 Map indicating the study area of the Dutch continental shelf



Source: Engeland, et al. 2010

A second boundary issue is related to the coastal area. The scope of ecosystem types to be included in marine accounts is still under discussion, although there are good arguments to include coastal ecosystem types like dunes, coastal wetlands etc. The delineation of the ecosystem services provided by either land or water is also not always be straightforward. For example, tourism and recreation with regard to the North Sea will be land based (i.e. beach recreation etc. for a more elaborate discussion see Chapter 5). After consultation with the advisory group, it was decided for the current project to place the border at the high water mark, but to include ecosystem services related to tourism and recreation in the current project.

[4] The Wadden Sea is an intertidal zone in the southeastern part of the North Sea, forming a shallow body of water with tidal flats and wetlands.

Structure of the report

In this report, we basically follow step 1 to 4 of the flow chart presented in figure 1.1 to describe the structure and results of this pilot project[5]. In chapter 2 a short description of the SEEA EEA accounting framework is provided, both for the terrestrial and marine environment. In chapter 3, the ecosystem type map and the extent account (step 1 in figure 1.1) is presented. The condition of ecosystems (step 2) is described in chapter 4 of this report. For the selected condition indicators, a more detailed analysis is made for the different ecosystem types of the DSC. Chapter 5 describes the supply and use of ecosystem services (step 3 and 4) for the Dutch North Sea area. Chapter 6 summarizes important policy uses of the natural capital accounts. In chapter 7 recommendations for further improvements and extensions of the accounts are provided for a potential follow up project. In chapter 8 the main conclusions are drawn.

[5] Steps 5 and 6 of figure 1.1 are not in scope for this pilot project, but can be covered during a potential follow up of this project.

2. The SEEA EEA accounting framework

2.1 The SEEA EEA: objective and implementation

The SEEA EEA provides a coherent framework for ecosystem accounting, which integrates measurements of ecosystem extent, ecosystem condition and the flows of ecosystem services with measures of economic and other human activities (UN et al., 2014a). The SEEA EEA provides a complementary approach to the SEEA Central Framework (CF) by providing a consistent and coherent synthesis of current knowledge regarding an accounting approach to the measurement of ecosystems[6]. It takes a spatially-explicit approach to natural capital accounting, building on the SEEA CF's approach to accounting for individual environmental assets.

A prime motivation for ecosystem accounting is awareness of the fact that distinct analyses of ecosystems and the economy do not encompass the vital relationship between people and the environment in which we live. The standard approaches to the measurement of the economy focus largely on economic and other human activities, as reflected in the activity of markets. Ecosystem accounting aims to shed light on the non-market activity associated with ecosystems and to integrate the information obtained with relevant market-related data. It is anticipated that individual and societal decisions concerning the use of the environment will be better informed through the use of information sets that are developed based on recognition of the relationship between ecosystems and economic and other human activities (SEEA EEA; par. 1.3).

The aim of linking Ecosystem Accounts with more general statistical accounts is the integration of environmental and economic information for application in policy discussions. Within this context, the more specific objectives in establishing an accounting structure are:

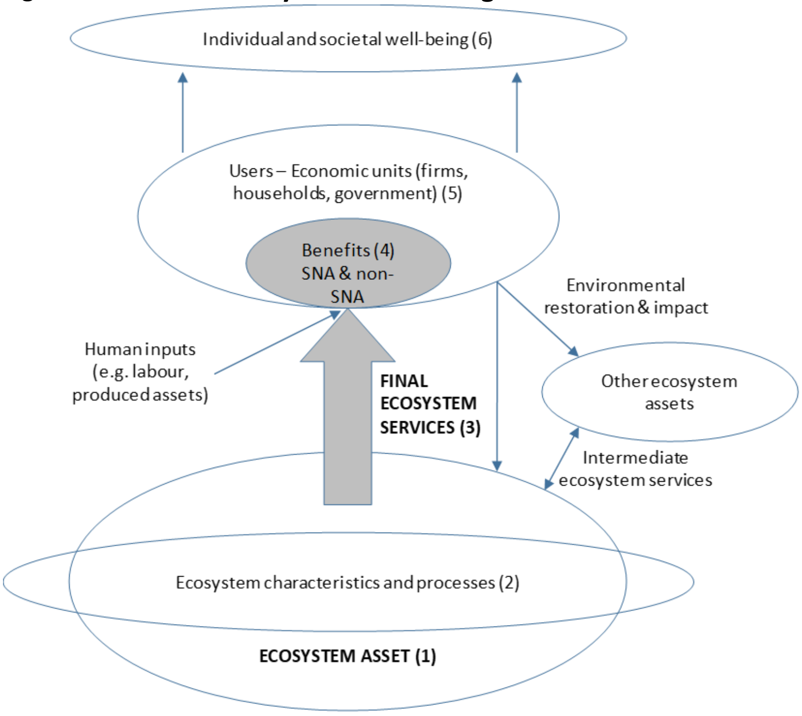
a) Organizing information on the environment from a spatial perspective, describing, in a coherent manner, linkages between ecosystems and economic and other human activities;
b) By applying a common, coherent and integrated set of concepts, classifications and terminology, the accounting structure provides a platform for the organization of data and research, allowing for systematic comparison and indicator production and providing the common international language and opportunity for comparison;
c) Allowing connections to be made to environmental-economic information compiled following the guidelines of the SEEA Central Framework. This should aid in the understanding of (i) the contribution of ecosystem services to economic production, consumption and accumulation, (ii) the attribution of degradation, restoration and enhancement of ecosystems to economic units and (iii) the development of more comprehensive measurement of national wealth;
d) Identifying information gaps and key information requirements.

2.2 SEEA EEA Accounting framework

The ecosystem accounting framework from the SEEA EEA (2012) provides a framework for placing information on ecosystem assets, ecosystem services, the benefits generated from ecosystem services and human well-being, in context, and has six main elements (Figure 2.1).

[6] The SEEA Central Framework is an international statistical standard to measure the interrelations between the economy and the environment. It consists of a consistent framework of accounts that measure physical flows, environmental assets and monetary activities (UN et al., 2014b).

Figure 2.1 The SEEA Ecosystem accounting framework



Source: SEEA EEA 2.20; SEEA TR 2.2.

SNA: System of National Accounts, the detailed description of the national economy.

1) Ecosystem assets

Ecosystem assets are the basic building blocks of the framework. They represent the *stock* of ecosystems. The first step in ecosystem accounting is to describe the various biotic and abiotic components within an ecosystem asset. An ecosystem asset is a distinct spatial area (SEEA EEA 2.12) and is defined as a '*contiguous areas covered by a specific ecosystem type (e.g. a single deciduous forest)*'. The spatial delineation of an ecosystem asset is required for accounting purposes and should be considered a statistical representation of ecosystems. Based on common characteristics, ecosystem assets can be aggregated to an ecosystem type (ET) classification (e.g. forests, cropland, build up areas, etc.).

2) Ecosystem characteristics and processes

Each ecosystem asset has a range of relevant ecosystem characteristics and processes that together describe the functioning of the ecosystem. While each ecosystem asset is uniquely defined, ecosystem processes will generally operate both within and across individual ecosystem assets. Intra-ecosystem and inter-ecosystem flows represent intermediate or supporting ecosystem services provided by an ecosystem to itself and to other ecosystems. An example of an intermediate service is the nursery service from coral reefs underpinning the supply of fish for harvest in the open oceans. The focus of ecosystem accounting (and of this report) is on final ecosystem services.

3) Final ecosystem services

Each ecosystem asset may generate certain final ecosystem services, which are defined as *contributions of ecosystems to benefits used in economic and other human activities*. Final ecosystem services encompass a wide range of services provided to economic units (households, firms, government, non-profit institutions). The Common International Classification of Ecosystem Services (CICES) divides ecosystem services into three groups: (1) provisioning services; (2) regulating services; and (3) cultural services. Generally, provisioning services are related to the material benefits of environmental assets, relating to the supply of food, fibre, fuel and water.

Regulating and cultural ecosystem services are related to the non-material benefits of environmental assets. Regulating services concern filtration, purification, regulation and maintenance of air, water, soil, habitat and climate. Cultural services concern the activities of individuals in, or associated with, nature.

4) Benefits

The benefits to which ecosystem services contribute are either SNA benefits or non-SNA benefits, i.e. benefits already included in the measurement of the System of national accounts or not. The contribution of ecosystem services to SNA benefits is already included in the volume and value of goods and services (products) produced by economic units. Examples are agricultural crops, drinking water, clothing, and tourism. The contribution to non-SNA benefits is not yet included. These are benefits that accrue to individuals or society generally, but that are not produced by economic units. Examples are clean air and carbon sequestration.

5) Users

For each supply of final ecosystem services, there is a corresponding use that leads to the production of either an SNA or a non-SNA benefit. For each use associated with the production of benefits, there is an associated user. Users are economic units (households, firms, government, non-profit institutions). Hence, every flow of final ecosystem services represents an exchange between an ecosystem asset (the supplier) and an economic unit (the user).

6) Individual and societal well-being

Both SNA and non-SNA benefits contribute to individual and societal well-being.

2.3 Accounts of the SEEA EEA

In SEEA EEA five core ecosystem accounts are distinguished:

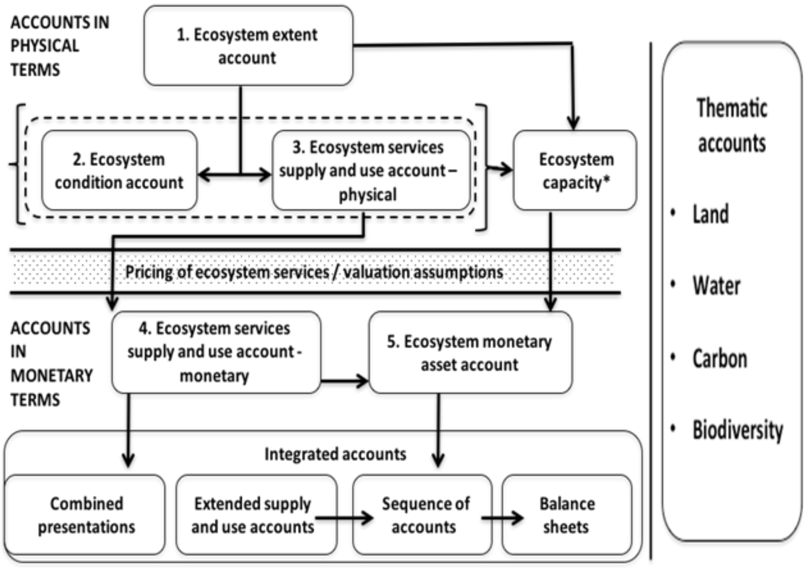
1. The ecosystem **extent account** (the area that represents the different ecosystem types);
2. The ecosystem **condition account** (the state or the environmental quality of the ecosystems, measured by different indicators);
3. The **physical ecosystem services supply and use accounts** (showing how much services do the ecosystems provide and who is using them);
4. The **monetary ecosystem services supply and use accounts** (showing the monetary value of services provided by the ecosystems);
5. The ecosystem **monetary asset account** (for tracking stocks and changes therein (additions and reductions) of ecosystem assets in monetary terms, based on valuation of the (future) ecosystem services).

In addition, there are so-called thematic ecosystem accounts that could be developed, such as the carbon account and the biodiversity account, which gives an explicit description of certain parts of the ecosystem that might be of particular interest to policy makers.

This set of ecosystem accounts reflects the complete coverage in accounting terms for all ecosystem assets and ecosystem services for a given ecosystem accounting area in both physical and monetary terms. However, these accounts and the information they contain will not function in isolation. Two connections with other accounts are relevant. The first link concerns the integration of ecosystem accounting information with the standard economic accounts, following SNA, in monetary flow accounts and balance sheets. The second link is to various kinds of the 'classic accounts' with some longer history, the SEEA Central Framework (CF) accounts (UNSD et al., 2014). These SEEA-CF accounts and other thematic accounts, focus on particular resources and flows such as water, energy, timber, fish, soil and land.

The linkages between the various ecosystem accounts are shown in Figure 2.2.

Figure 2.2 Connections between the different ecosystem accounts



Source: UN et al., SEEA-EEA-Technical Recommendations, 2018; slightly adjusted.

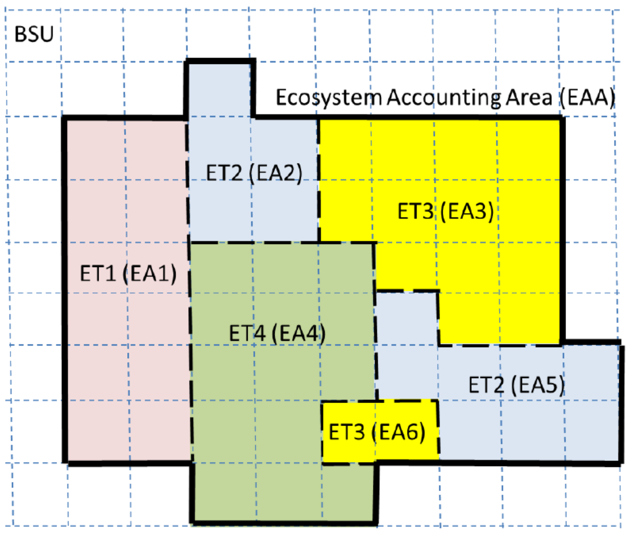
3. The ecosystem type map and the extent account

3.1 Delineation of ecosystem assets for the marine environment

Ecosystem accounting requires delineation of areas within a country, including its terrestrial, coastal and marine areas, into mutually exclusive units that represent ecosystem assets (EAs). Ecosystem assets are contiguous areas representing individual ecosystems (e.g. a deciduous forest or a tidal marsh) that form the conceptual base for accounting and the integration of relevant statistics. In practice, given that accounts are normally developed at aggregated scales such as countries, large watersheds and so on, it may be difficult to analyse, record and report data for each individual EA. It is therefore relevant to analyse accounting variables, such as ecosystem condition and ecosystem service supply, at a more aggregated level reflecting information for EAs of the same type, the Ecosystem Type (ET). Ecosystem Types (ETs) thus show aggregations of individual Ecosystem assets (EAs) representing a specific type of ecosystem (e.g. marshlands).

A stylised example of the spatial structure of the ecosystem extent account is shown in Figure 3.1 (UN et al., 2018). The figure also shows the relationships between EA, ET and EAA. The ecosystem accounting area (EAA) is defined by the thick black boundary line. Six distinct EAs are delineated and these have been classified to four different ET. The figure also incorporates the basic spatial unit (BSU), the spatial unit of measurement. The BSU may correspond, as in Figure 3.1, to a grid cell in a spatial information system or to individual polygons in cases where a vector based approach to ecosystem extent accounting is pursued.

Figure 3.1: Relationships between spatial areas in ecosystem extent accounting



Source: SEEA EEA Technical recommandations (UN et al., 2018)

No international standard exists yet for an ecosystem type classification. A key research issue of the current SEEA EEA revision is to choose a reference classification that covers the terrestrial, freshwater and marine environment. Probably the IUCN RLE ecosystem typology will we selected for this purpose (Keith et al., 2019 in prep). National ecosystem classifications can be cross walked with this reference classification to ensure international comparability.

An important difference between terrestrial and marine ecosystems is that marine ecosystems are not concentrated near one surface (i.e. the air-land interface), but may extent throughout the water column and the underlying sediment. The question is whether and how the spatial approach of SEEA EEA for ecosystem assets can be applied to the marine environment. Basically, there are two approaches to define ecosystem assets for the marine environment[7]:

1) Following the spatial approach of SEEA EEA, each area of the sea/ocean belongs to one single ecosystem asset. When we follow the reasoning that the ecosystem asset is best envisaged as a three-dimensional column, an ecosystem for the seas/oceans would include the entire water column and underlying sediments delineated by a certain area.

2) Particularly for deep waters, ecosystems near the seafloor may be very different from near the surface waters. Accordingly, it then makes more sense to describe the condition, biodiversity and supply of services for different ecosystem assets. For example, a distinction could be made to 'seabed' and 'marine waters' ecosystem assets. As the water column and the underlying sediment may constitute of different ecosystems, we may discern different ecosystem assets.

Internationally, the recommendation is to follow the first mentioned spatial approach for more shallow marine environments and to use the three-dimensional approach for the deeper parts of the oceans. The Dutch part of the North Sea is relatively shallow and therefore the spatial approach is expected to work well and was therefore chosen for this study. Furthermore, this approach is fully in line with the approach used in SEEA EEA for the terrestrial environment.

3.2 Ecosystem type map for the Dutch part the North Sea

The ecosystem type map for the Dutch part of the North Sea (Figure 3.2) was constructed by 'enriching' the Dutch "Natuurtypenkaart" for the North sea (Wageningen University, 2011) with information on the estuaries (Waddenzee and the Scheldes). Basically, the classification in the ecosystem types is based on the following characteristics (see also Table 3.3):

1. Water depth (4 classes: 0–10 meter, 10–20 meter, 20–30 meter, > 30 meter)
2. Summer stratification of the water column
3. Salinity (distinguishing marine waters from transitional waters)
4. Sediment type
5. Protection status

The first four characteristics are ecological in nature, the last one (protection status) is an anthropogenic characteristic (based on political decisions). The resulting map consists of five main ecosystem types (shoreline systems, transitional waters, marine shelf shallow waters, marine shelf medium depth waters, marine shelf deep waters). On the basis of the sediment type, these five main ecosystem types are further disaggregated into a total of 12 ecosystem subtypes. More detailed descriptions of these ecosystem types are provided in the report by Wageningen University (2011). The ecosystem types are based on abiotic characteristics. Adding ecosystem characterisation based on some biotic characteristics may allow to identify some very specific ecosystems in the DSC, such as oyster and mussel banks, reefs, sea grass meadows etc. This needs to be further investigated.

[7] See also https://seea.un.org/sites/seea.un.org/files/documents/EEA/seea_eea_revision_wg1_discussion_paper_1.3_atmospheric_and_ocean_units.pdf

Figure 3.2 Ecosystem type map of the Dutch part of the North Sea

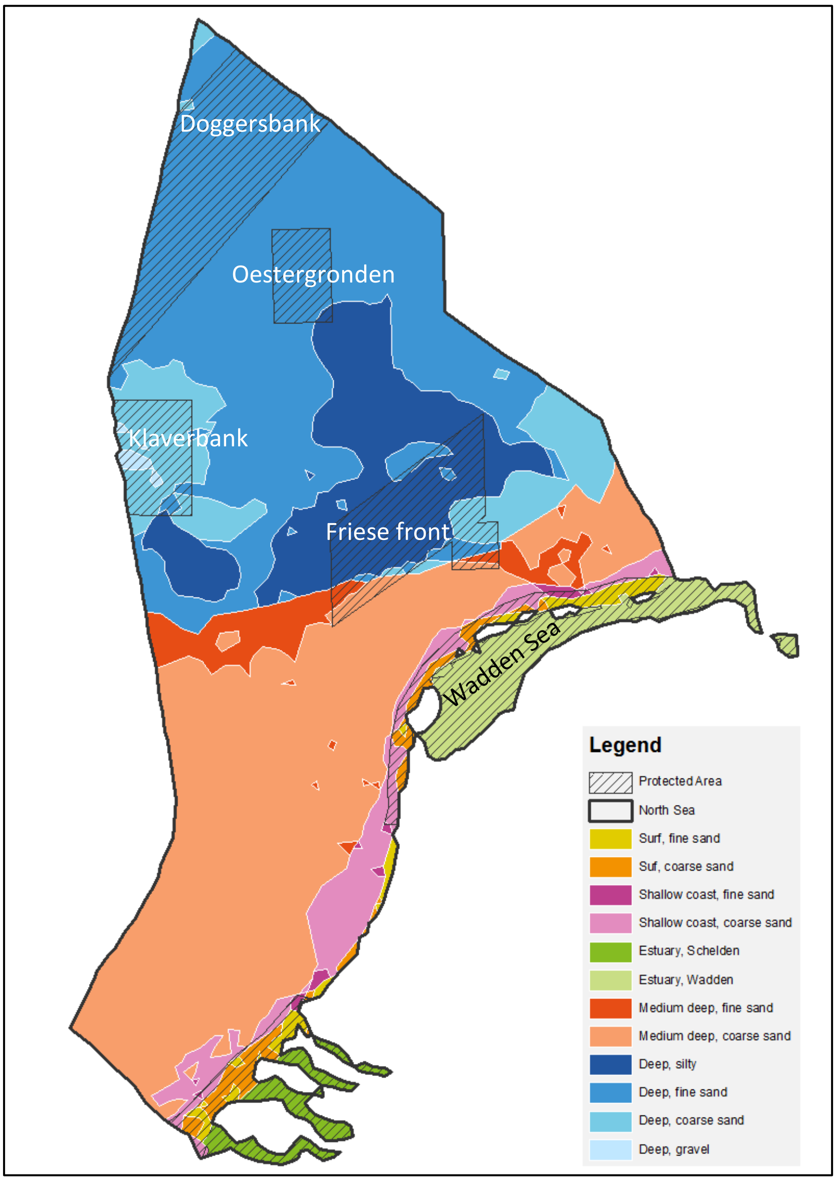


Table 3.3 Ecosystem type classification for the North Sea with its key abiotic characteristics

CODE	Ecosystem subtypes	Water depth (meter)	Salinity	Summer stratification	Sediment type (mean gransize)
E.1	Schelden (estuary)	0-10	strong salinity gradient	no	
E.2	Wadden (tidal flats)		weak salinity gradient		
B.1	Fine sand bottom	0-10	high salinity	no	< 210 µm
B.2	Coarse sand bottom				> 210 µm
K.1	Fine sand bottom	10-20	high salinity	no	< 210 µm
K.2	Coarse sand bottom				> 210 µm
M.1	Fine sand bottom	20-30	high salinity	no	< 210 µm
M.2	Coarse sand bottom				> 210 µm
Z.1	Muddy / fine sand bottom	> 30	high salinity	yes	< 210 µm and/or >15 % mud
Z.2	fine sand / coarse sand bottom				210-420 µm
Z.3	Coarse sand bottom		high salinity		>420 µm
Z.4	Gravel bottom				> 50% gravel and > 2 mm

These ecosystem types can also be further disaggregated based on the protection status. Significant parts of the Dutch continental shelf are being protected by Dutch or international law. These areas are protected under the Habitats Directive, the Birds Directive or the Marine Strategy Framework Directive. It is important to notice that there are important differences between the protected areas with respect to the economic activities that are allowed there.

3.3 Set up of the extent account

The first core account of the SEEA EEA framework is the extent account. This account is the start of the sequence of a full set of ecosystem accounts. It aims to organise information on the area, or extent of the different ecosystem types in a specific area. A good balance is needed between scale of analysis, data availability and derivable (policy) questions. The extent account is based on the ecosystem type map (Figure 3.2), which was compiled and decided upon during the initial phase of the project.

The structure of a basic ecosystem extent account for the marine environment is shown in Table 3.4. The structure of the rows reflects the basic logic of asset accounts as described in the SEEA Central Framework with an opening extent (showing the sum of the delineation areas / marine zones for each particular ecosystem type at the DCS, expressed in km^2, a closing extent, additions and reductions.

Table 3.4 Structure of the extent account for the marine environment (in ha)

	Ecosystem type											
	Dunes with permanent vegetation	Active coastal dunes	Beaches	Coastal wetlands	Estuaries	Intertidal areas	Port entrance / Harbour mouth	Coastal	Shelf	Open ocean	Etc.	Total
	1	2	3	4	5	6	7	8	9	10	11	.. ..
Opening extent												
Additions to extent												
Managed expansion												
Natural expansion												
Upward reappraisal												
Reductions to extent												
Managed regression												
Natural regression												
Downward reappraisal												
Net change in extent												
Closing extent												

During the present pilot project, only information for one year is being compiled, which means that there will be no information about additions and reductions. In contrast to the terrestrial environment, it is not expected that the extent of the different marine ecosystem types will change much in time. The characteristics that determine the ecosystem type, i.e. water depth, salinity, stratification and sediment size, are unlikely to change much on an annual basis. Only the protection status may change in time. Accordingly, once the ecosystem classification has been established the extent account will not require regular updates and can be used as the basis for future updates of the other accounts.

3.4 The extent account for the Dutch part of the North Sea

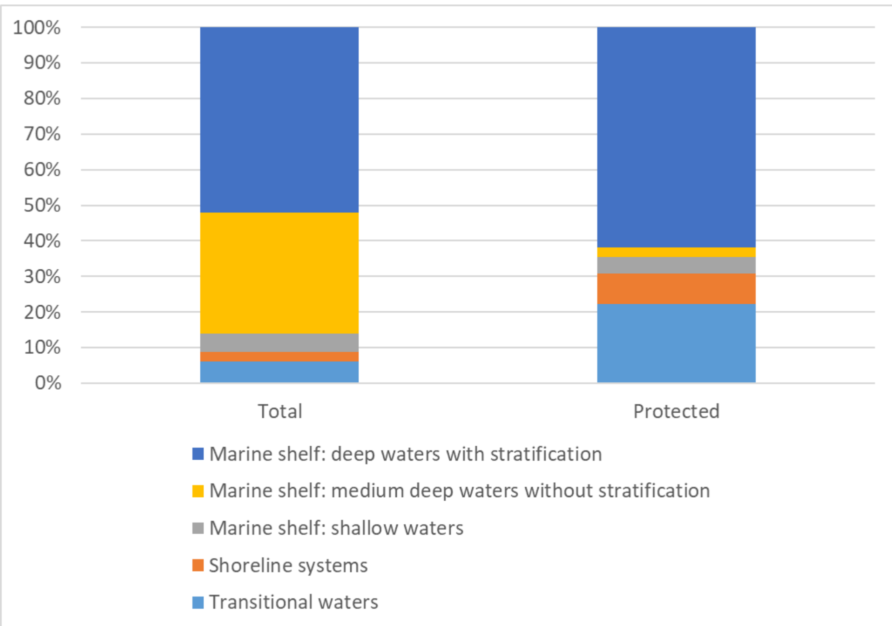
In table 3.5 the extent account for the Dutch part of the North Sea is presented. It contains the same 5 main ecosystem types and 12 ecosystem subtypes presented in the previous section. Looking at the main ecosystem types, the deep waters (52%) and medium depth waters (34%) of the marine shelf cover by far the largest area, with the other three ecosystem types spanning only 17% of the total area. With regard to the ecosystem subtypes, the picture is also dominated by two types (M.2 and Z.2), which together are covering more than 62% of the Dutch continental shelf.

Table 3.5 Extent account for the Dutch Continental Shelf

Main Ecosystem type	CODE	Ecosystem subtypes	TOTAL KM^2	Share in total %	Protected KM^2	Protected %
Transitional waters	E.1	Schelden	1.018	1,6%	1.018	100,0%
	E.2	Wadden	2.740	4,4%	2.575	94,0%
Shoreline systems	B.1	Fine sand bottom	738	1,2%	599	81,1%
	B.2	Coarse sand bottom	927	1,5%	821	88,6%
Marine shelf: shallow waters	K.1	Fine sand bottom	226	0,4%	74	32,8%
	K.2	Coarse sand bottom	2.979	4,8%	672	22,6%
Marine shelf: medium deep waters without stratification	M.1	Fine sand bottom	2.080	3,4%	150	7,2%
	M.2	Coarse sand bottom	18.991	30,6%	266	1,4%
Marine shelf: deep waters with stratification	Z.1	Muddy / fine sand bottom	7.748	12,5%	2.265	29,2%
	Z.2	fine sand / coarse sand bottom	19.547	31,5%	6.026	30,8%
	Z.3	Coarse sand bottom	4.838	7,8%	1.618	33,4%
	Z.4	Gravel bottom	137	0,2%	135	98,5%
TOTAL	-	-	**61.968**		**16.219**	-
Average	-	-	-		-	**26,1%**

In total a little over a quarter of the Dutch part of the North Sea, including the transitional waters and shoreline system, are (to some degree) protected, but there are significant differences between the ecosystem types (Figure 3.6). The shoreline systems and the transitional waters are almost completely protected, while for the marine shelf medium depth waters this is only a few percent. Deep marine shelf waters with coarse sediments (Z4) are almost all protected. This ecosystem is located in the west of the DSC on the so called Klaverbank. Sediments with gravel and coarse sands provide an ecosystem type with an high ecological diversity.

Figure 3.6 Extent on ecosystems on the DSC: total area and protected areas



4. The condition account

4.1 Introduction

The second core account of the SEEA EEA framework is the condition account. The condition account provides insight into how the biophysical condition of ecosystems change, and how those changes may influence the flows of ecosystem services supplied by those ecosystems. The ecosystem condition account is compiled in physical terms using a variety of indicators for selected characteristics. Indicators in the ecosystem condition account reflect the general condition or state of an ecosystem and the relevant trends in that condition. For the marine environment. these indicators may reflect such aspects as the occurrence of species, sediment characteristics, water quality, and ecological processes (e.g. net primary production). The indicators selected should be relevant for policy and decision making, for instance because they reflect policy priorities (e.g. preservation of native habitat), pressures on ecosystems (e.g. deposition levels of acidifying compounds versus critical loads for such compounds) or the capacity of ecosystems to generate one or more services (e.g. attractiveness of the ecosystem for tourism). Generally, different ecosystem types require different indicators (SEEA EEA technical recommendations, 2018, par. 4.5).

The structure of the ecosystem condition account is focused on recording information at two points in time, i.e. it presents information on the condition of different ecosystem types at the opening and closing of the reference accounting period (e.g. one year). Ecosystem condition accounting is particularly useful when accounts are developed for multiple years in order to record trends/changes in ecosystem condition (and, as relevant, the spatial variability of these trends). In the columns are the ecosystem types, in the rows are different indicators for condition (Table 4.1). The present pilot project only contains information for one year, which means that there will be no information about additions and reductions. One of the recommendations of this project is to repeat and extend this measurement, so that in the future, a full set of condition accounts (including opening and closing account) can be compiled.

Table 4.1 Example of an ecosystem condition account

		Proxy ecosystem type (based on land cover)														
		Artificial surfaces	Herbaceous crops	Woody crops	Multiple or layered crops	Grassland	Tree-covered areas	Mangroves	Shrub-covered areas	Regularly flooded areas	Sparse natural vegetated areas	Terrestrial barren land	Permanent snow and glaciers	Inland water bodies	Coastal water and inter-tidal areas	Sea and marine areas
Example indicators of condition		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Vegetation (e.g. native cover)	Opening condition															
	Closing condition															
Water quality (e.g. turbidity, pH)	Opening condition															
	Closing condition															
Soil (e.g. erosion, pH, nutrients)	Opening condition															
	Closing condition															
Carbon (e.g. net primary productivity)	Opening condition															
	Closing condition															
Biodiversity (e.g. species richness)	Opening condition															
	Closing condition															
Habitats (e.g. fragmentation)	Opening condition															
	Closing condition															
Overall index of condition	Opening condition															
	Closing condition															

Source: SEEA EEA Technical recommandations (UN et al., 2018).

4.2 The condition account for the Dutch North Sea

The selection of condition indicators for this project was based on three criteria: 1) policy relevance, 2) data availability, and 3) the relevance to measure changes in the environmental quality of ecosystems. Furthermore, the time available for this pilot project allowed to include only a restricted number of indicators.

With regard to policy relevance, indicators were selected that directly relate to the European Marine Strategy Framework Directive. The main goal of the Marine Strategy Framework Directive is to achieve Good Environmental Status of EU marine waters by 2020[8]. The Directive defines Good Environmental Status (GES) as: "The environmental status of marine waters where these provide ecologically diverse and dynamic oceans and seas which are clean, healthy and productive" (Article 3). GES means that the different uses made of the marine resources are conducted at a sustainable level, ensuring their continuity for future generations. To help Member States interpret what GES means in practice, the Directive sets out, in Annex I, eleven qualitative descriptors which describe what the environment will look like when GES has been achieved:

1. Biodiversity is maintained
2. Non-indigenous species do not adversely alter the ecosystem
3. The population of commercial fish species is healthy
4. Elements of food webs ensure long-term abundance and reproduction
5. Eutrophication is minimised
6. The sea floor integrity ensures functioning of the ecosystem
7. Permanent alteration of hydrographical conditions does not adversely affect the ecosystem
8. Concentrations of contaminants give no effects
9. Contaminants in seafood are below safe levels
10. Marine litter does not cause harm
11. Introduction of energy (including underwater noise) does not adversely affect the ecosystem

In the Netherlands, a monitoring programme for the Marine Strategy Framework Directive has been set up. Indicators have been selected to monitor the different descriptors of the MSFD[9]. This indicator set was the starting point for selecting condition indicators for the current project.

Next, data availability with regard to the indicators of the MSFD was checked, and more specifically, whether spatial explicit data was available for these indicators. In some cases maps already are available. In other cases, only data for some specific measuring points were available. In these cases spatially explicit maps were created. Most data could be obtained via the Marine Information and Data Centre (IHM)[10]. The IHM is a collaborative venture between the Ministry of Infrastructure and the Environment and the Ministry of Economic Affairs. The IHM serves as a platform for finding and sharing data about the North Sea. This website features a range of functionalities for making marine information and data, including research data, accessible to everyone. Marine data from the central government can be centrally retrieved from this website.

Finally, not all indicators are directly relevant to measure the environmental quality of ecosystems. Only those indicators were selected that can unambiguously be related to an improvement of deterioration of its environmental quality.

Accordingly, 11 indicators were selected and included in this study(see Table 4.2). For some descriptors no indictors were selected. In some cases, indicators are difficult to define and are still being developed, for example for food webs and underwater energy/sound. In other cases, indicators are available but not spatially explicit data, for example contaminants in seafood. It should be noted that this selection is only a first step in the

[8] https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-7/index_en.htm
[9] https://www.noordzeeloket.nl/en/policy/europese/background-documents/documents-marine/@166937/marine-strategy-0/
[10] https://www.informatiehuismarien.nl/uk/

compilation of a condition account for the DCS, more work and research is needed to include a more comprehensive set of indicators in the future.

Table 4.2: Indicators investigated and selected for the condition account, classified according to the MSFD descriptors

Descriptor Marine Directive	INDICATOR	Source	Year	Included in this study
1. Biodiversity	Benthos	RWS	2015-2016	X
	Guillemot	CBS		
	Total birds	CBS		
	Porpoises	CBS		
2. Non-indigenous species				
3. Fish populations				
4. Foodwebs				
5. Eutrophication	Inorganic nitrogen concentration surface water	RWS	2016	X
	Dissolved O2 concentration	Emodnet	2016	X
	Phosphorus concentration surface water	Emodnet	2016	X
	Chlorophyl a	RWS	2016	X
	Phytoplankton	RWS	2016	X
6. Seafloor integrity	Benthic fishing intensity	RWS		X
7. hydrographical conditions	Water depth	RWS	2017	
	PAR (optisch)			
	Salinity	RWS	2016	X
	Sea surface temperature	RWS	2016	
8. Contaminents	Tributyltin concentration surface water	RWS	2015-2106	X
	Lead concentration surface water	Emodnet	2016	X
	PCB concentration surface water	RWS	2015-2016	X
9. Contaminants in seafood				
10. Marine litter				
11. Energy/underwater sound				

Data for the condition account were compiled by crossing the maps for individual condition indicators with the ecosystem type map (Figure 3.2). Accordingly, the indicators were calculated for each specific ecosystem type.

Below, the first condition account for the DSC is presented (table 4.3). As yet, the data are not represented for protected and non-protected areas separately, as this requires a data validation, but this can be done in a future next phase of the accounts. On the longer term, the value added of this information can be improved significantly by adding a reference level for each indicator, as well as a time series, to be able to determine trends in the development of the various indicators.

Descriptor Marine Directive	INDICATOR	unit	*Transitional waters*		*Shoreline systems*		*Marine shelf: shallow waters*		*Marine shelf: medium deep waters without stratification*		*Marine shelf: deep waters with stratification*			
			Schelden	Wadden	Fine sand bottom	Coarse sand bottom	Fine sand bottom	Coarse sand bottom	Fine sand bottom	Coarse sand bottom	Muddy / fine sand bottom	Fine sand / coarse sand bottom	Coarse sand bottom	Gravel bottom
1. Biodiversity	Benthos	n/m2	4,76	1,98	2,57	2,67	1,85	2,53	1,15	1,46	1,84	0,63	1,42	30,71
	Total birds													
	Porpoises													
5. Eutrophication	Inorganic nitrogen concentrations	mg/l	0,73	0,20	0,58	0,53	0,47	0,41	0,17	0,20	0,07	0,11	0,16	0,18
	Dissolved O_2 concentration	umol/l	264,7	299,5	279,5	285,1	287,2	292,7	279,4	284,2	291,9	284,9	281,4	277,0
	Phosphate concentration surface water	umol/l	2,72	0,82	0,82	0,80	0,69	0,73	0,53	0,68	0,81	0,51	0,44	0,44
	Chlorophyl a	ppm	4,14	3,11	5,36	4,99	4,53	5,28	2,83	2,99	2,04	2,04	2,56	2,76
	Phytoplankton	10^6n/l	2,41	1,60	2,11	2,33	1,85	2,64	1,45	1,62	1,05	1,27	1,35	1,63
6. Seafloor integrity	Benthic fishing intensity	rel	178,0	162,7	204,6	196,7	190,2	203,2	209,3	205,1	198,9	200,0	207,3	220,8
7. hydrographical conditions	Water depth													
	PAR (optisch)													
	Salinity	promille	31,32	32,52	31,62	31,71	31,825	32,25	33,19	33,27	34,02	33,95	33,465	28,14
	Sea surfce temperature													
8. Contaminents	Tributyltin concentrations	ppb	3,31	2,45	3,80	3,27	3,34	3,21	1,635	1,915	1,34	1,105	1,245	1,035
	Lead concentration surface water	ppm	56,3	43,8	51,0	55,2	50,8	51,6	45,7	39,8	41,0	43,7	48,7	52,2
	PCB concentration surface water	ppb	1,71	1,32	1,59	1,33	1,43	1,42	1,07	1,67	1,35	0,95	0,65	0,43

Table 4.3: values of condition indicators for the Dutch part of the North Sea

4.3 Results for some individual indicators

In this section, we look at some indictors in more detail. The underlying maps and the indicator values for the main ecosystem types are presented

4.3.1 Salinity

The salt content of the sea water (measured in promille) is not constant through the whole North Sea. Especially near the coast, the influx of fresh water (from rivers and lakes) will have a lowering effect on the salt content of the sea. Through the North Sea, there is a network of measuring points where the salinity of the water is monitored. Figure 4.4 was constructed using data from those measuring points. Salinity is the lowest near the coast of Zeeland, Zuid- and Noord-Holland. Here, the inflow of fresh water is the highest. When we look at the average salinity per ecosystem types we also see lower values for shoreline systems and higher values for deeper waters (Figure 4.5).

General remark: as yet only a few measuring points in het Dutch Wadden Sea were included in the calculations. As a consequence of that, this part of the research area is not covered very well, sometimes resulting in a wrong salinity level (wrong colour on the map). In a future update it will be investigated whether more measuring points could be included to conduct a good monitoring of the Dutch Wadden Sea.

Figure 4.4: Salinity map for the Dutch continental shelf

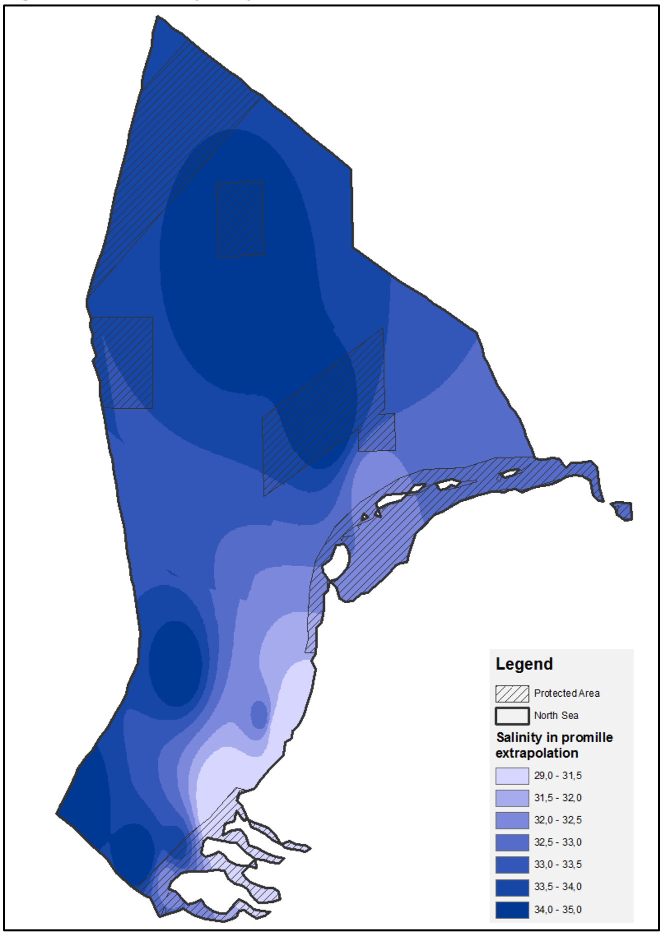
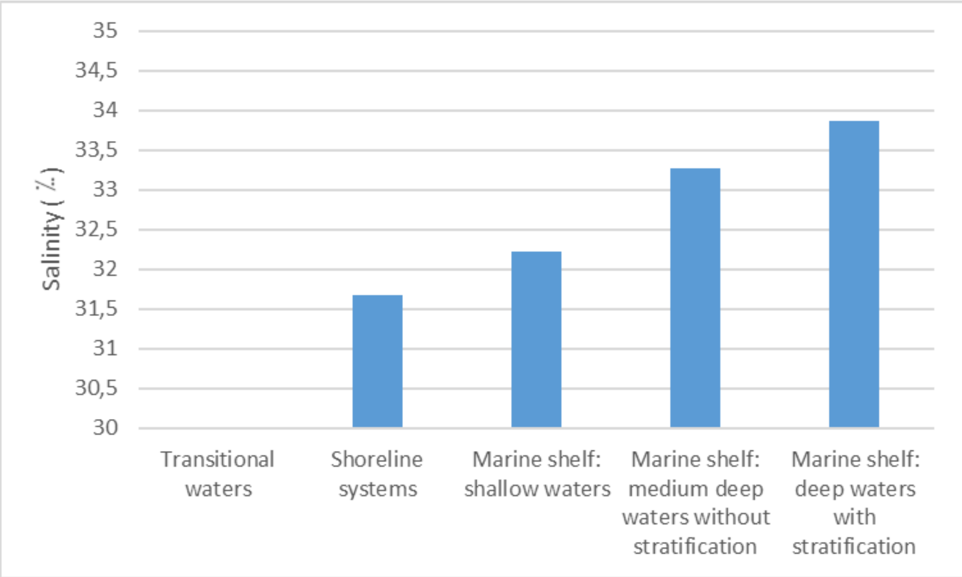


Figure 4.5: Salinity concentrations for the main ecosystem types



4.3.2 Inorganic nitrogen

Eutrophication is a process driven by the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, leading to increased primary production, changes in the balance of organisms and water quality degradation. The consequences of eutrophication are undesirable if they degrade ecosystem health and biodiversity and/or the sustainable provision of ecosystem services[11].

Nitrogen and phosphorous are the primary inorganic nutrients responsible for the eutrophication of marine waters. Nitrogen and phosphorous occur naturally in marine waters, transferred from land via streams, rivers and runoff of rainwater, but also from degradation of organic material within the water. However, human inputs of nutrients to the environment has increased the load of nitrogen and phosphorous to the oceans.

The standards for nutrient concentrations in salt water have been recorded in the OSPAR convention and the Water Framework Directive (WFD). The OSPAR Convention is the "Convention for the Protection of the Marine Environment of the North-East Atlantic". OSPAR applies a standard of 15 µMol / l for dissolved inorganic nitrogen (0.21 mg N / l) in the North Sea outside the coastal zone. OSPAR applies a much lower standard for the Wadden Sea (0.01 mg N / l) than the WFD (0.46 mg N / l)[12].

Figure 4.6 shows the map for inorganic nitrogen concentrations the Dutch North Sea area. The nitrogen levels are the highest close to the mainland and are lower on the open sea. For comparison, the map shows that the nitrogen levels at some points near the coast are around 10 times higher than at the lowest points on the North Sea.

[11] https://ec.europa.eu/environment/marine/good-environmental-status/descriptor-5/index_en.htm
[12] https://www.clo.nl/indicatoren/nl0254-vermestende-stoffen-in-zout-oppervlaktewater

Figure 4.6: Map showing the inorganic N for the different ecosystem types of the DCS

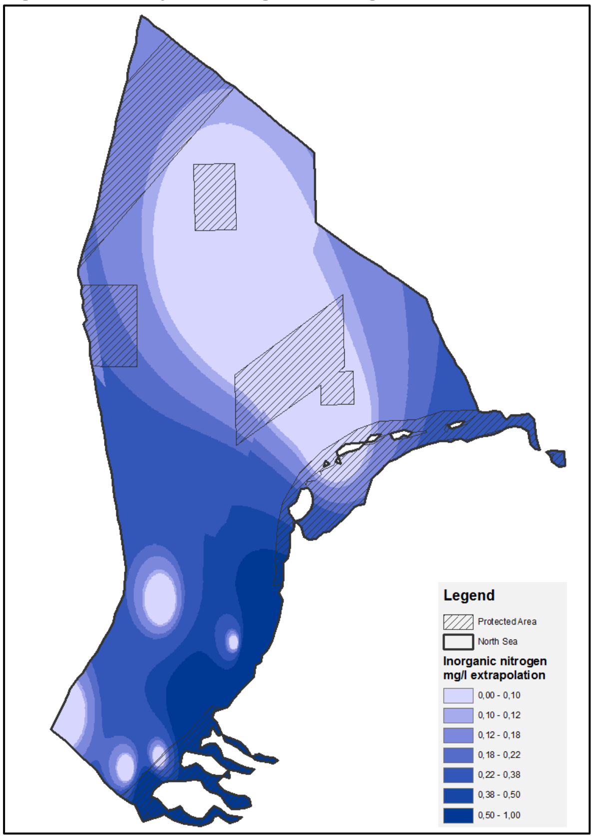
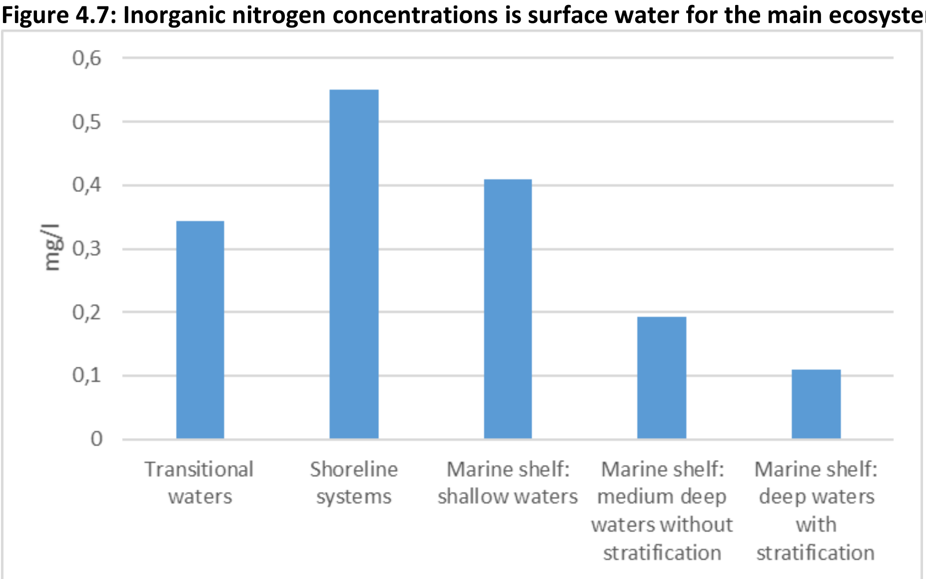


Figure 4.7 shows the inorganic nitrogen concentrations for the five main marine ecosystem types. Concentrations are highest for shoreline systems and the shallow depth marine shelf. These two ecosystem types lie offshore the provinces South and north Holland, which have a high influx from rivers and other drainage. Nitrogen concentrations are somewhat lower for transitional waters, but here concentrations are very high for the Scheldt estuaries, but lower for the Wadden Sea. Nitrogen concentrations are lowest for the deep marine shelf waters, which are relative far from the land area.

Figure 4.7: Inorganic nitrogen concentrations is surface water for the main ecosystem types

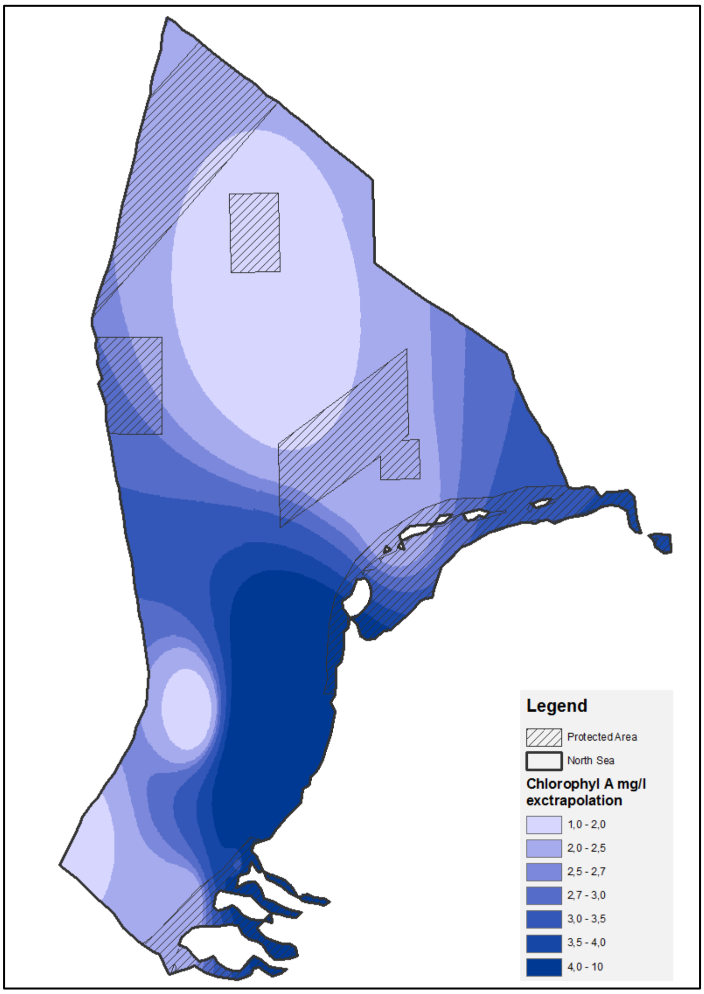


4.3.3 Chlorophyll

At the base of the ocean food web are single-celled algae and other plant-like organisms known as phytoplankton. Like plants on land, phytoplankton use chlorophyll and other light-harvesting pigments to carry out photosynthesis. The chlorophyll concentration in the surface water is an indication of how much primary production is occurring in the surface of the ocean.

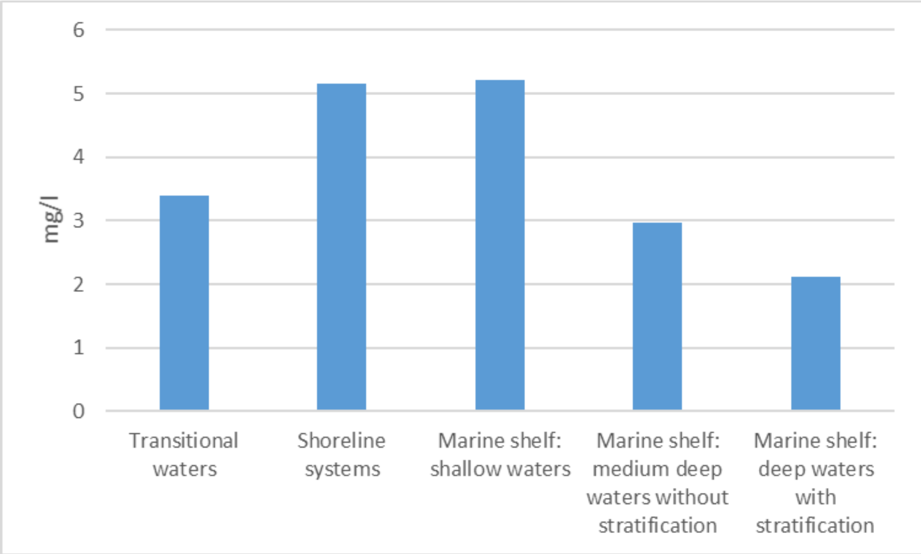
Chlorophyll concentration's in surface water are highest close to the coast and relatively lower farther offshore. There is a close resemblance with the inorganic nitrogen concentrations (Figure 4.8). This reflects that primary production to a large extent depends on the availability of nutrients.

Figure 4.8: Map showing the Chlorophyll content for the different ecosystem types of the DCS



Chlorophyll concentrations are high offshore the coast of North and South Holland, which is reflected in the high values for shoreline systems and the shallow marine shelf.

Figure 4.9: Chlorophyll concentration in surface water for the main ecosystem types

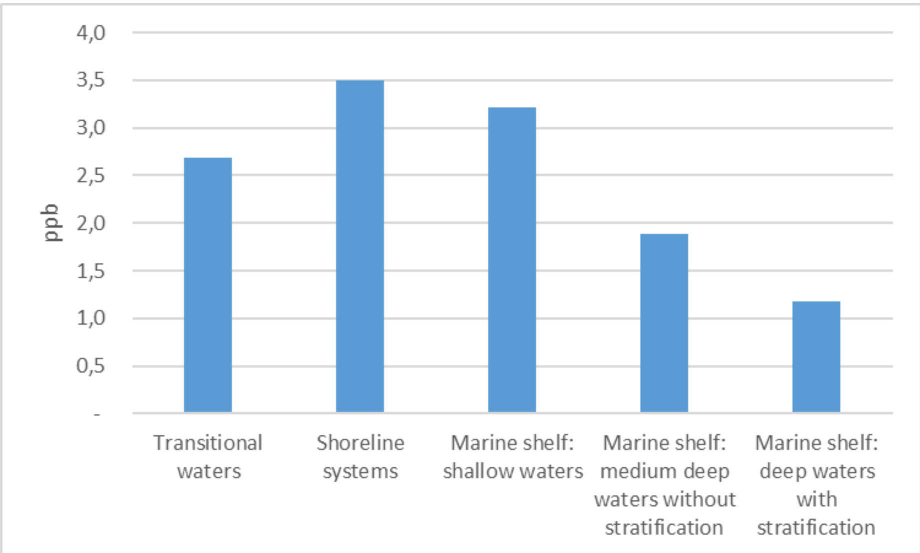


4.3.4 Tributyltin

Tributyltin (TBT) is an umbrella term for a class of organotin compounds which contain the $(C_4H_9)_3Sn$ group. For 40 years TBT has been used as an antifouling agent in paints applied to boats and fishnets. Tributyltin is toxic for among other shellfish. In Europe regulations are in place to reduce and ban the use of tributyltin. Tributyltin is thus an important example of a pressure indicator that can be monitored in the marine environment.

Tributyltin concentrations in surface water are highest in ecosystem types near the coast (Figure 4.10).

Figure 4.10: Tributyltin concentrations in surface water for the main ecosystem types



5. Physical supply and use tables for ecosystem services

5.1 Introduction

The third core account of the SEEA EEA framework are the physical supply and use tables for ecosystem services. The supply of ecosystem services by ecosystems and the use of these services by economic units, including households, is one of the key features of SEEA ecosystem accounting. Ecosystem services are the flows that reflect the link between ecosystems and economic and human activities. Their measurement is thus central to the ambition to integrate environmental information fully into the existing national accounts (UN et al., 2018).

The ecosystem service accounts can be compiled both in biophysical and monetary terms. When compiled in biophysical terms, each ecosystem service will have a particular measurement unit as well as interpretation; for example, tons of fishing or the number of tourists visiting nature areas. As a consequence, there can be no aggregation of the different ecosystem service types, nor can there be a direct interpretation of the economic significance of an ecosystem service in comparison to another. In this study we will focus on the physical accounts for ecosystem services, the monetary valuation of the ecosystem services and the ecosystem assets is left for future analyses.

In this chapter we will first describe which ecosystem services are relevant for the marine environment, and in particular for the Dutch part of the North Sea. Second, we will describe the ecosystem services we selected for this study, both with regard to the total supply of the services as their spatial allocation to ecosystem type (when possible). Finally, the physical supply and use tables are presented.

5.2 Ecosystem services for the marine environment

There are many ecosystem services that are relevant for the marine environment. A useful point of departure is the CICES (Common International Classification of Ecosystem Services) classification that was developed in Europe as an international classification system for ecosystem services. The first fully operational version CICES (V4.3) was published in 2013. On the basis of the experience gained since then by the user community, its structure and scope has been reviewed, and a fully revised version (V5.1) is now available[13]. The work on 'Version 5.1' was informed by a review of the relevant scientific literature, key inputs were also provided from the experience of using CICES gained in the EU-led work on Mapping and Assessment of Ecosystems and their Services (MAES).

CICES Version 5.1 has been extended to more formally cover abiotic ecosystem outputs. Although the focus of SEEA ecosystem accounting is on biotic services, it is recognized that it may be relevant to incorporate measures of abiotic services to consider the full range of benefits from a defined area (SEEA EEA TR 5.57). Including abiotic services is particularly relevant for the marine environment, as abiotic services such as the extraction of minerals and the generation of wind power play an important role in this environmental realm. However, it is also acknowledged that the boundary between *biotic* and *abiotic* ecosystem services is often difficult to define in practice. For example, with regard of cultural services it is almost impossible to distinguish the biotic and abiotic components of ecosystems with regard to ecosystem services related to nature related recreation and tourism. Note that the use of space is not included in CICES as an abiotic ecosystem service. This issue is still under investigation under the SEEA EEA research agenda, and will be discussed in more detail below.

[13] https://cices.eu/

CICES 5.1 also includes an identification of relevant ecosystem services for the marine environment (Table 5.1)[14]. As can be seen from this table, ecosystem services for the marine environment cover a broad scope of services, including both biotic and abiotic provisioning, regulation and cultural services.

5.3 Selection of the ecosystem services for this study

The main criteria for selecting ecosystem services for this project were 1) relevance for the Dutch North Sea area, 2) data availability, and 3) budget limitations. For this study we made a first assessment of the relevance of particular ecosystem services for the North Sea area. We evaluated whether the ecosystem service is (at this moment) providing a significant economic or social benefit. With regard to biotic provisioning services marine fishing (biomass by wild animals for nutrition) is the most important. Aquaculture (provision of biomass by reared animals), i.e. shellfish culture and finfish culture, plays a less important role in the Dutch North Sea economy (Statistics Netherlands, 2017c), but may become more important in the future. Important abiotic provisioning services for the DCS include the supply of mineral and non-mineral inputs for nutrition, materials and energy (i.e. the extraction of oil, gas, sand, gravel, wind). The provision of seawater (mainly for cooling purposes) is of less importance. Several regulating services are important for the North Sea area, including mediation of wastes and toxic substances, regulating lifecycle condition and habitat, regelation of baseline flows and extreme events (for example flood protection), regulation of water condition and regulation of atmospheric condition (for example by carbon sequestration). Cultural services for the North Sea area mainly relate to recreation and tourism (physical and experimental interaction with the environment), the intellectual, spiritual and symbolic interactions with the environment are more difficult to define and measure.

Based on this evaluation we selected the following ecosystem services for which data is available:

1. Marine fishing
2. Extraction of sand and gravel
3. Extraction of gas and oil
4. Provision of wind
5. Provision of space
6. Nature related recreation and tourism

For the moment no regulating services have been included, as first more extensive research is needed with regard to the exact definition of these services, data requirements and spatial modelling.

[14] In CICES the relevance for the marine environment is only indicated for the biotic services, we added the relevance for biotic services.

Table 5.1 CICES version 5.1: ecosystem services relevant for the marine environment and relevance for the North Sea area

Biotic/ abiotic	Section	Division	Code	Group	Relevance for North Sea area	Included in this study
Biotic	Provisioning	Biomass	1.1.2.1	Cultivated aquatic plants for nutrition, materials or energy	low	
			1.1.4.1	Reared aquatic animals for nutrition, materials or energy	medium	
			1.1.5.1	Wild plants for nutrition, materials or energy	low	
			1.1.6.1	Wild animal for nutrition, materials or energy	high	Marine fishing
		Genetic material from all biota (including seed, spore or gamete	1.2.1.1	Genetic material from plants, algae or fungi	low	
			1.2.2.1	Genetic material from animals	low	
	Regulation & Maintenance	Transformation of biochemical or physical inputs to ecosystems	2.1.1.1	Mediation of wastes or toxic substances of anthropogenic origin by living processes	High	
			2.1.2.1	Mediation of nuisances of anthropogenic origin	medium ?	
		Regulation of physical, chemical, biological conditions	2.2.1.1	Regulation of baseline flows and extreme events	High	
			2.2.2.1	Lifecycle maintenance, habitat and gene pool protection	High	
			2.2.3.1	Pest and disease control	?	
			2.2.4.2	Regulation of soil/ sediment quality	low?	
			2.2.5.2	Water conditions	High	
			2.2.6.1	Atmospheric composition and conditions	High	
	Cultural	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	3.1.1.1	Physical and experiential interactions with natural environment	High	Nature related tourism / recreation
			3.1.2.1	Intellectual and representative interactions with natural environment	medium	
		Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	3.2.1.1	Spiritual, symbolic and other interactions with natural environment	medium	
			3.2.2.1	Other biotic characteristics that have a non-use value	low?	
Abiotic	Provisioning	Water	4.2.1.1	Surface water used for nutrition, materials or energy	medium	
		Non-aqueous natural abiotic ecosystem outputs	4.3.1.1	Mineral substances used for nutrition, materials or energy	high	Extraction of sand/ gravel/ oil/ gas
			4.3.2.1	Non-mineral substances or ecosystem properties used for nutrition, materials or energy	high	Generation of electricity from wind power
	Regulation & Maintenance	Transformation of biochemical or physical inputs to ecosystems	5.1.1.1	Mediation of waste, toxics and other nuisances by non-living processes	medium	
		Regulation of physical, chemical, biological conditions	5.2.1.1	Regulation of baseline flows and extreme events	high	
			5.2.2.1	Maintenance of physical, chemical, abiotic conditions	low	
	Cultural	Direct, in-situ and outdoor interactions with natural physical systems that depend on presence in the environmental setting	6.1.1.1	Physical and experiential interactions with natural abiotic components of the environment	high	
			6.1.2.1	Intellectual and representative interactions with abiotic components of the natural environment	low	
		Indirect, remote, often indoor interactions with physical systems that do not require presence in the environmental setting	6.2.1.1	Spiritual, symbolic and other interactions with the abiotic components of the natural environment	low	
			6.2.2.1	Other abiotic characteristics that have a non-use value	low	

5.4 Data, methodology and results

1) Wild animals for nutrition: marine fishing

The fishing industry in the Netherlands consists of trawler fisheries, large-scale high sea fisheries (taking place outside the DSC), mussel farming and aquaculture. The Dutch fleet in the Greater North Sea consists of about 500 vessels (ICES, 2017). The largest part of the demersal fleet is the beam trawl fleet (275 vessels, of which 85 are >24 m and 190 are < 24 m) that operates in the southern and central North Sea, targeting sole (*Solea solea*; dominant in value) and plaice (*Pleuronectes platessa*; dominant in volume) as well as other flatfish species. Fisheries in the Netherlands contribute ca. 400 million euro to GDP, which is 0,05 % (2018). Over the past years the number of self-employed in the fishing industry has declined and the profitability of the industry is under pressure.

Fisheries biomass generated by marine and coastal ecosystems forms the basis for a range of potential ecosystem service flows and benefits, ranging across provisioning services (food for consumption), cultural services (fish catch for recreational enjoyment), and regulating services (influencing the biomass of other fish populations) (Dvarkas et al., 2019). Each of these service flows and benefits impacts different end users and therefore rely on different methods for their measurement and valuation. Here we focus on the marine fish caught for sale and consumption, which is an important biotic provisioning service provided by the marine environment.

Total supply of the service

A variety of approaches are available for quantifying the physical stocks and flows associated with the provisioning service of fisheries biomass. These include the use of catch statistics to quantify flows as well as the use of survey trawls, modelling approaches, satellites, and novel genetic techniques to estimate the size and distribution of the biomass stock (Dvarkas et al., 2019). Each approach has its own embedded uncertainties and different costs associated with the collection and support of the data collection. Our first entry here is using catch statistics that are available for the North Sea area. Data is available for a) total amount of different fish species caught, b) the location where the fish is landed, c) the nationality (flag) of the operating ships, and d) the area where the fish is harvested (ICES fishing areas). Figure 5.3 shows total fish landed in the Netherlands from the North Sea according to the three ICES regions. Note that the Northern North Sea Region (Iva) does not overlap with the DCS.

Figure 5.2 ICES fishing areas that overlap with the Dutch Continental Shelf

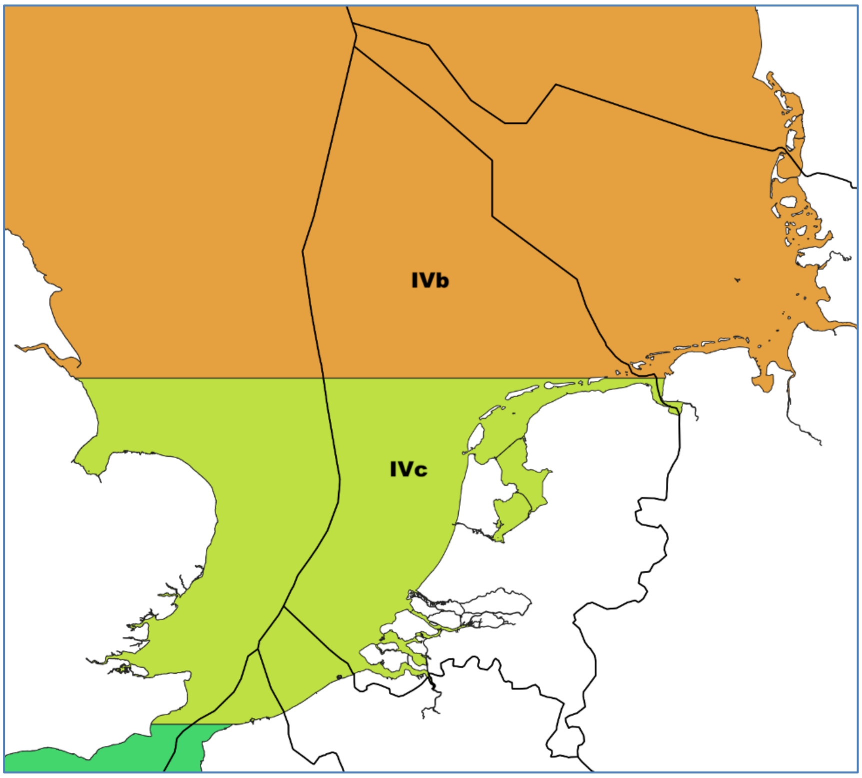
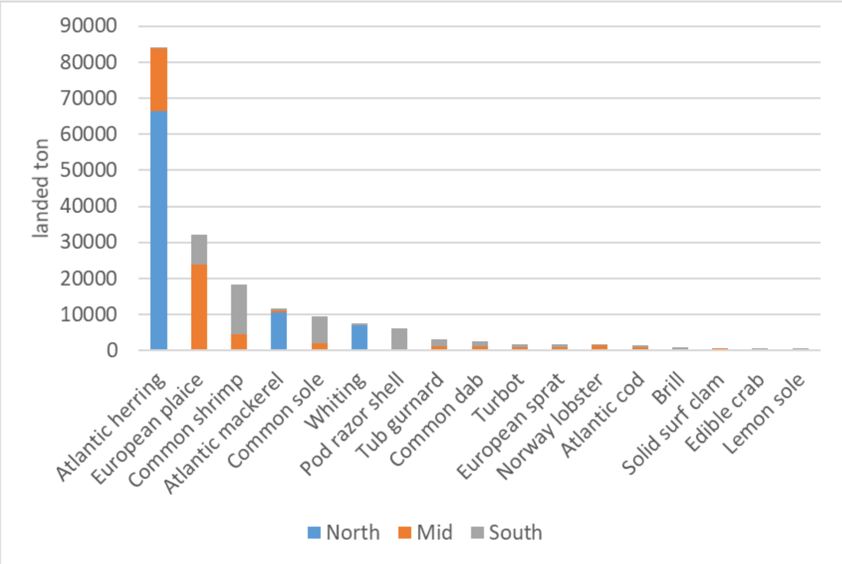


Figure 5.3 Fish from the North Sea landed in the Netherlands according to the three ICES regions (2016)



The national catch statistics do not allow to determine the total fish caught on the DCS, as these include all fish caught in the North Sea that was landed in the Netherlands. As can be seen in Figure 5.2, the DCS constitutes only a small part of ICES areas IVb and IVc of the North Sea . In addition, this data does not include fish caught in the DCS that was landed outside the Netherlands. The required data, however, has been calculated by 'The Sea Around Us', a research initiative at The University of British Columbia (located at the Institute for the Oceans and Fisheries, formerly Fisheries Centre) that assesses the impact of fisheries on the marine ecosystems of the world[15]. Data was calculated for individual countries EEZs based on a combination official reported data (mainly extracted from the Food and Agriculture Organization of the United Nations (FAO) Fisheries) and reconstructed estimates of unreported data (including major discards). Data are also provided by taxon (fish species) and fishing country. This data provides the best measure for the total supply of fish biomass from the DCS.

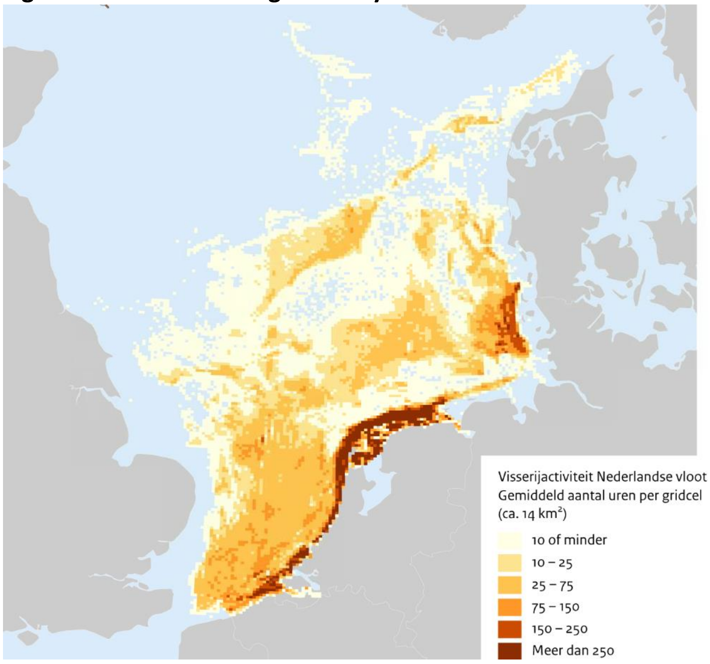
Table 5.4 Total fish catch in the Dutch EEZ

1000 ton	2010	2011	2012	2013	2014
Cockles	0	1,4	1	4,6	4,7
Sole	5,2	4,7	4,8	5,6	5,6
Haddock	0,5	1,3	1,2	0,9	0,6
Shrimp	12,1	8,8	9,6	12	13,8
Sprat	34,9	21,3	10,2	12,9	13,5
Whiting	4,7	4	3,9	4,2	4,6
Dab	12,9	11,2	11,2	12,2	11,3
Cod	3,2	2,9	3,2	2,3	2,7
Plaice	21,1	20,5	20,4	22,7	20,9
Herring	3,9	6,7	11,5	13,3	12,9
Others	62,4	70,2	28,4	54,1	51,8
TOTAL	160,9	153	105,4	144,8	142,4

Source: Gibson et al., (2015)

[15] http://www.seaaroundus.org/

Spatial allocation of the service
A specific challenge is to determine the spatial contributions of the various coastal and marine ecosystem assets to the production of fish biomass that is eventually harvested (or used for other purposes). The ICES fishing areas are too large to allocate the provision of fish biomass to specific ecosystem types as defined in this study (see figure 5.2). For demersal fish (that feed and live on or near the bottom of the sea), data is available for benthic fisheries (average period 2011–2015; see figure 5.5). As a first approximation, this could be used to allocate demersal fish species like plaice and sole to specific ecosystem types (see table 5.13). In contrast, for pelagic fish species (that live in the water column) it may be less useful to allocate them to the detailed ecosystem types that are related to sediment type. Here, an allocation to more aggregated ecosystem types may be more appropriate (i.e. shallow waters – medium depth – deep waters). A future option to provide a more detailed and up to date allocation of marine fishing to ecosystem type may be to use (big) data from AIS (Automatic Identification System) for fishing vessels.

Figure 5.5 Benthic fishing intensity


Source: Wageningen Marine research

2) Mineral substances used for nutrition, materials or energy: extraction of sand and gravel
Sand and gravel are not only collected from the mainland, but also from the North Sea. It is often used for land reclamation, for the protection of the coast, for maintaining shipping channels on the DCS and as fill sand for (infrastructural) projects[16]. Extraction of sand and gravel is an abiotic provisioning service. The service is here defined as the total amount of sand and gravel extracted from the marine environment.

Total supply of the service
The UEPG (European Aggregates Association) publishes physical data on aggregates production, both marine aggregates and total aggregates production[17]. Between 2010 and 2017, total extraction varied between 64 and 80 million tonnes.

[16] Due to roundness, sand from the marine environment is not used for concrete fabrication.
[17] http://www.uepg.eu/statistics/estimates-of-production-data/data-2017

Table 5.6 Total extraction of sand and gravel on the DCS (source UEPG)

	TOTAL production *million tonnes*	Marine aggregates *million tonnes*	Marine aggregates *% of total*
2010	76	17	22,4
2011	73	15	20,5
2012	83	16	19,3
2013	64	15	23,4
2014	73	14	19,2
2015	80	12	15,0
2016	75	13	17,3
2017	78	16	20,5

Spatial allocation of the service

No extraction data is available for specific mining and dredging sites. As an approximation, the extraction of sand and gravel could be distributed to all areas where sand and gravel extraction is allowed (see Figure 5.10). As a map of the dredging areas was not readily available the spatial allocation to ecosystem type has not been done for this study, but this would be feasible for a follow up study. However, it would be preferable to use location specific extraction data when available.

3) Mineral substances used for nutrition, materials or energy: extraction of oil and gas

The Netherlands has significant reserves of natural gas as well as some smaller oil deposits. On the DCS some oil, but mainly natural gas is extracted. Since their discovery, these stocks have been exploited to meet the demand of users in the Dutch economy and to facilitate exports to foreign countries. Extraction of natural gas and oil contributes significantly to GDP. Over the last twenty years, the benefits arising from oil and gas extraction, contributed on average 3 percent to total revenue of the Dutch Government. The ecosystem service could be defined as the total amount of natural gas and oil extracted from the environment (however, see also discussion at the end of this section whether the extraction of subsoil assets should be considered as an ecosystem service or not).

Total supply of the service

Data on total gas and oil extraction on the Dutch continental shelf is obtained from the annual reports on energy resources (Ministry of Economic Affairs and Climate, 2018). Total natural gas extraction decreased from 20921 million Nm^3 in 2010 to 12179 Nm^3 in 2017 (Table 5.7). Oil extraction varied in this period between 1307 and 705 Sm^3.

Table 5.7 Extraction of natural gas and oil from the DCS

Natural gas								
milion Nm3	2010	2011	2012	2013	2014	2015	2016	2017
Land	60475	55882	56233	63044	50697	35640	34588	29661
continental shelf	20921	18551	17900	17004	15258	14049	13334	12179
Total	81396	74433	74133	80048	65955	49689	47923	41840
Oil								
1000 Sm3	2010	2011	2012	2013	2014	2015	2016	2017
Land								
continental shelf	982	848	884	710	1.133	1.307	957	705
Total	1.262	1.270	1.323	1.314	1.810	1.656	1.136	1.114

Spatial allocation of the service

In principle, it is possible to allocate the total production of gas and oil to specific areas in the North Sea (so called extraction blocks of ca. 400 km²). Due to time constraints this has not yet been done. The key question, however, is whether the extraction of natural gas and oil should be included as an ecosystem service in the ecosystem accounts. Oil and gas are extracted from the deep subsoil. The deep subsoil does not belong to the marine ecosystem assets, i.e. the biotic and abiotic components interacting as a functional unit. This is also in line with the recent findings for defining ecosystem assets for the SEEA EEA revision (Statistics Netherlands, 2019). As such we recommend not to include extraction of gas and oil as an ecosystem service provided by the marine environment. It may be added as a memorandum item to the account. In addition, the presence of oil platforms may be added as a pressure indicator in the condition account (see previous chapter).

3) Non-mineral substances or ecosystem properties used for nutrition, materials or energy: generation of wind power

The Netherlands, like the other countries surrounding the North Sea, use the windy areas near the coast for the generation of wind energy. In the Netherlands, wind energy is harvested on the DCS since 2006. Wind generation is an abiotic ecosystem service, it can be defined as the total electricity generated by wind power.

Total supply of the service

The total generation of wind energy is available from the annual statistics on renewable energy (Table 5.8).

Table 5.8 Electricity generation from wind power on the DCS

		2010	2011	2012	2013	2014	2015	2016	2017	2018*
Total wind energy	mln kWh	3993	5100	4982	5627	5797	7550	8170	10569	10549
on land	mln kWh	3315	4298	4193	4856	5049	6420	5901	6869	6919
on sea	mln kWh	679	802	789	771	748	1130	2269	3700	3630

In 2018, 3630 kWh of electricity was produced by offshore wind farms (Statistics Netherlands, Statline, 2019). This equals 34 percent of the total national production of wind energy, a significant increase compared to the 17 percent in 2010. In the near future a significant increase is expected as new wind farms are currently being constructed.

Spatial allocation of the service

Wind power generation cannot be published for the individual wind farms. However, a spatial allocation could be done based the capacity of the individual windfarms which is known.

4) provision of space

The North Sea is one of the most intensively used marine areas of the world. Economic activities on the North Sea include marine shipping, fisheries, mining of sand and gravel, oil and gas exploration, generation of wind power, military activities, recreation and tourism. In addition, certain areas have been protected for nature preservation, which means restricted use for other economic activities. Accordingly, space is becoming more and more scare and its use has to be regulated[18].

Whether the provision is of space is an ecosystem service is still under debate. For example, this service is not included in the CICES 5.1 classification. The provision of space clearly contributes to benefits for several economic activities, the question is whether this contribution can be attributed to ecosystems. A recent paper for the SEEA EEA revision states that 'clear distinctions need to be made between uses which benefit from the ongoing and intrinsic qualities of the ecosystem, and uses which are largely or entirely neutral as far as the type

[18] https://www.noordzeeloket.nl/beleid/noordzee-2030/

or nature of the ecosystem is concerned. This suggests that navigation should be included as a service (notwithstanding any difficulties in measuring or valuing the service). In contrast, passive storage of waste should not be viewed as an ecosystem service' (Harris, 2019). For the marine environment, this means that the provision of space for several activities (but maybe not all) could be included. The scope of activities to be included however needs further investigation.

Total supply of the service

The actual use of space on the DCS is known from policy documents and spatial planning maps (Table 5.9). Note that in some cases several economic uses are compatible within the same space. In other cases, activities exclude each other, for example, fisheries are excluded from areas closed for nature. It needs to be investigated whether only single use or also multiple use of a certain area should be included as an ecosystem service and how to account for this in the tables (i.e. avoiding double counting of areas).

5.9 Actual use of space in the Dutch part of the North Sea

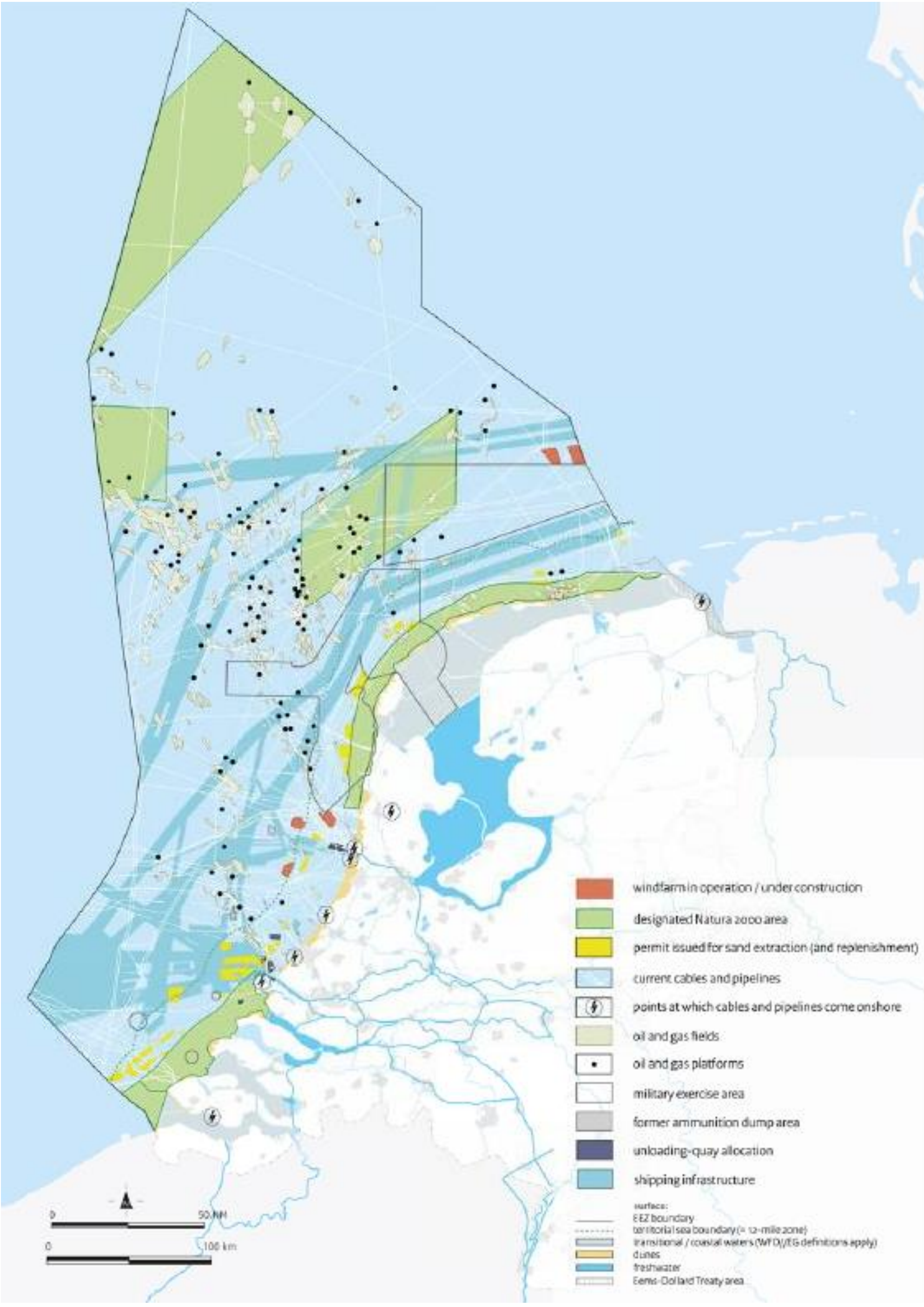
Designated use		Numbers	Use of space in km²
Oil and gas extraction		161 platforms	126
Commercial surface mineral extraction		13 mln m³/jr	60-90 in 5 years
Coastal replenishment sand extraction		12 mln m³/jr	
Dumping sites for dredging		6	37
Cables (in use)		3300 km	3300
Pipelines		4500 km	4500
Shipping routes			3600
Military exercise zones		5	4200
Wind energy	Completed Under construction Planned	228 MW 730 MW 3450 MW	43 125 575 at 6MW/km²
Nature conservation areas	Voordelta Vlakte van de Raan North Sea Coastal ZoneDogger Bank Frisian Front Cleaver Bank		924 175 1445 4715 2880 1235
Fishing			EEZ and territorial waters minus areas closed for nature and energy
Dutch part of the North Sea			58000 (approx.)

Source: Policy document on the North Sea 2016-2021

Spatial allocation of the service

Spatial maps are available for the actual use of space on the DCS (see Figure 5.10). Accordingly, these maps can be used to allocate the use of space to different ecosystem types. This spatial allocation has only partly been done in this study, as some spatial data was not readily available (see table 5.13).

5.10 Actual use of space on the DCS (2015)



Source: Policy document on the North Sea 2016-2021

5) Nature related tourism and recreation

Tourism is an important economic activity. In the Netherlands, tourism activities contribute 28.6 billion euro to value added, which is 4.3 % of total GDP (2017), and provides approximately 761 thousand jobs (source: Dutch Tourism Satellite accounts, Statistics Netherlands). Ecosystems play an important role in outdoor recreation by providing attractive environments for leisure activities. We can distinguish between nature related tourism and nature related recreation, where recreation considers only single-day activities and tourism includes only multiple-day activities away from home (with at least one overnight stay at an accommodation).

The supply of the ecosystem service 'nature related recreation', in physical terms, is usually expressed as the number of outdoor activities, such as hiking, cycling, outdoor sports, relaxing in nature areas, etc. As these activities revolve around the interaction with the direct environment, the provision of an attractive surrounding is considered to be the ecosystem service. For nature related tourism, the number of overnight stays is often taken as the measure of the ecosystem service. Both ecosystem services are allocated to the ecosystem where the activities or the overnight stays take place (CBS and WUR, 2017).

Defining nature related recreation and tourism for marine ecosystems is not straightforward. Some activities, like sailing, surfing and swimming can be directly linked to marine ecosystems. However, some recreational activities, for instance hiking and relaxing on the beach, will not take place in or on water but on the adjacent land area (i.e. beaches, coastal dunes). Similarly, overnight stays in hotels, camping sites or bungalows located near the sea also take place on land. As these activities in coastal areas are closely related to the marine environment, we here propose to include them in the marine ecosystem accounts, but allocate them to an 'extra' terrestrial ecosystem type, which in the case of the Netherlands would be 'coastal dunes and beaches'.

Total supply of the ecosystem service

The total supply of recreation and tourism related to the DCS is based on the results of Dutch natural capital accounts for the terrestrial environment (CBS and WUR, 2017). As hiking is the most popular outdoor recreational activity in the Netherlands, ranging from short strolls in the neighbourhood to day-hikes along long distance paths (NBTC-NIPO, 2015), hiking was used as the indicator for nature recreation. The total number of hiking activities in coastal areas (dunes and beaches) equals 2025 million hiking activities, which is 8 % of the total hiking activities in the Netherlands (2015). Hiking density in coastal areas is highest in the provinces Zuid Holland and Zeeland (Table 6.11). Obviously, in a future follow up study also other relevant recreational activities should be considered that are important for the marine environment such as water sports and recreation on the beach.

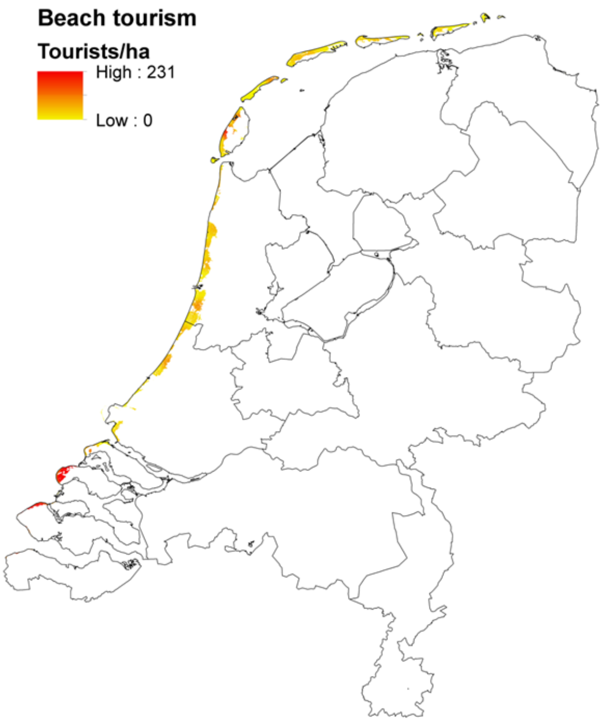
The ecosystem service nature tourism was modelled based on Dutch tourism statistics for provinces and tourism areas (NBTC-NIPO, 2015). Statistics are available for three main types of nature related tourism, namely nature and active tourism, beach tourism, and water sports. It can be assumed that these types of tourism are directly dependent on the of presence of (semi-) natural ecosystems. Here we selected only beach tourism, as this is directly related to the marine environment. Tourism statistics were combined with data on densities of beds (for land activities) and marinas (for water sports) for spatial disaggregation. Tourist activities were assumed to take place in the vicinity of accommodations and marinas. The total overnight stays in coastal areas (Dunes and beaches) equals 3.1 million which is 24 % of total overnight stays in non-urban environments. Beach tourists mostly stay in the provinces Noord Holland and Zuid Holland (Table 5.11).

Table 5.11 Data for beach tourism and hiking near the sea by province

Province	Beach tourism	Hiking sea, beach and dunes
	Number of tourists (x1000)	Mean number of hikers (x1000/ha)
Groningen	0	21
Friesland	129	13
Drenthe	0	0
Overijssel	0	0
Flevoland	0	0
Gelderland	0	0
Utrecht	0	0
Noord-Holland	327	71
Zuid-Holland	126	197
Zeeland	386	187
Noord-Brabant	0	0
Limburg	0	0

Beaches and dunes are important ecosystems for tourism in the Netherlands with a mean density of 22 tourists per ha. In 2015 there were over 1 million beach tourists in the Netherlands (visits including an overnight stay, excluding day trippers). Especially the province of Zeeland has a high density of beach tourists (Figure 5.12), with up to 231 beach tourists per ha.

Figure 5.12 Number of beach tourists per ha in the Netherlands in 2015.



5.5 Ecosystem services physical supply and use tables

The physical supply and use tables for ecosystem services record the flows of ecosystem services supplied by ecosystem assets (classified by ecosystem type) and used by economic units during an accounting period. Data in the ecosystem supply and use tables relate to a given ecosystem territory. This may be the national territory or any region on a sub-regional scale.

The supply table records which ecosystem types provide biophysical quantities of ecosystem services. This gives insight into the wide range of services that are offered by marine ecosystems. As the supply account is based on ecosystem service maps, locations of supply can be traced in detail.

The use table records which economic sectors (corporations, households, government, exports) benefit from the ecosystem services, following the classifications used in the national accounts. As can be observed from this table, many different economic activities benefit from ecosystem services provided by the marine ecosystems of the DCS.

		year	unit	Transitional waters		Shoreline systems		Marine shelf: shallow waters		Marine shelf: medium dpth waters without stratification		Marine shelf: deep waters with stratification				Coastal dunes and beaches	TOTAL
				E.1 Schelden	E.2 Wadden	B.1 Fine sand bottom	B.2 Coarse sand bottom	K.1 Fine sand bottom	K.2 Coarse sand bottom	M.1 Fine sand bottom	M.2 Coarse sand bottom	Z.1 Muddy / fine sand bottom	Z.2 fine / coarse sand bottom	Z.3 Coarse sand bottom	Z.4 Gravel bottom		
Provisioning services	**Marine fishing**	2014	1000 ton														142,4
	Herring	2014	1000 ton														12,9
	Shrimp	2014	1000 ton														13,8
	Sprat	2014	1000 ton														13,8
	Dab	2014	1000 ton														11,3
	Plaice	2014	1000 ton	0,0	1,4	2,0	2,0	1,9	2,0	2,0	1,9	1,8	1,9	1,9	2,0		20,9
	Sand and gravel extraction	2017	million ton														16
	Oil and gas extration																
	Gas	2017	milion Nm3	0	0	0	0	0	101	1912	5133	2818	1610	604	0		12179
	Oil	2017	1000 Sm3	0	0	0	0	0	6	111	297	163	93	35	0		705
	Wind energy generation	2017	mln kWh	0	0	0	0	0	1341	157	1080	0	0	1123	0		3700
	Provision of space																
	Oil and gas extraction	2015	km2	0	0	0	0	0	1	19	51	28	16	6	0		121
	Fisheries	2015	km2														
	Sand and gravel mining	2015	km2														
	Navigation (approaching areas)	2015	km2	0	0	85	46	58	1046	21	604	0	0	0	0		1861
	Navigation (total)	2015	km2														3 600
	Military activities	2015	km2														4200
	Wind generation	2015	km2	0	0	0	0	0	308	36	248	0	0	258	0		850
	Habitat and nurseries	2015	km2	1.018	2.575	599	821	74	672	150	266	2.265	6.026	1.618	135		12626
Cultural services	**Nature recreation**	2015	million hikers													2025	2025
	Nature tourism	2017	1000 stays													3101	3101

5.13 Physical supply table for ecosystem services

		year	unit	A - Agriculture, forestry and fishing	B,C - Mining and manufacturing	D - Electricity	E - Water supply, environmental services	F-H - Contruction, wholesale and transportation	I,R - Accommodation and food service, culture, sports and recreation	Other sectors	Export	Households	Government	TOTAL
Provisioning services	**Marine fishing**	2014	1000 ton	142										142
	Herring	2014	1000 ton	13										13
	Shrimp	2014	1000 ton	14										14
	Sprat	2014	1000 ton	14										14
	Dab	2014	1000 ton	11										11
	Plaice	2014	1000 ton	21										21
	Sand and gravel extraction	2017	million ton		16									16
	Oil and gas extration													
	Gas	2017	milion Nm3		12179									12179
	Oil	2017	1000 Sm3		705									705
	Wind energy generation	2017	mln kWh			3700								3700
	Provision of space													
	Oil and gas extraction	2015	km2		121									121
	Fisheries	2015	km2											
	Sand and gravel mining	2015	km2											
	Navigation (approaching areas)	2015	km2					1861						1861
	Navigation (total)	2015	km2					3 600						3 600
	Military activities	2015	km2										4200	4200
	Wind generation	2015	km2			850								850
	Habitat and nurseries	2015	km2										12626	12626
Cultural services	**Nature recreation**	2015	million hikers									2025		2025
	Nature tourism	2017	1000 stays									3101		3101

5.14 Physical use table for ecosystem services

6. Policy uses

Ecosystem accounts provide several important pieces of information in support of policy and decision making relating to environment and natural resources management. The overview below of important policy uses is based on par. 1.4 from the SEEA EEA technical recommendations (UNSD, 2018) and includes possible policy uses for both the physical and monetary ecosystem accounts.

1) Detailed, spatial information on ecosystem services supplied by the marine environment.
Ecosystem service supply accounts provide information on the quantity and location of the supply of ecosystem services. This gives insight in the wide range of services that are offered by the marine environment. This information is vital to monitor the progress towards policy goals such as achieving a sustainable use of ecosystem assets and preventing further loss of biodiversity. Defining and quantifying ecosystem services and the factors that support or undermine them is needed to highlight the importance of all types of ecosystems. Protection of the natural environment is highly important not just because of its (potentially incalculable) intrinsic value, but also because of the services that provide clear economic benefits to businesses, governments and households.

The information from the accounts should also be highly relevant for the spatial planning of for instance, infrastructure projects. For example, the potential impacts of different locations for wind farms on the overall supply of ecosystem services can be easily observed and analysed.

2) Monitoring the status of ecosystems
The set of ecosystem accounts provide detailed information on changes in status of the marine environment. The condition account reveals the status using a set of physical indicators. These indicators could be aligned with the list of 'descriptors used to determining Good Environmental Status (GES) in the Marine Strategy Framework Directive (MSFD).

In this study we have not put together monetary accounts, since that was considered to be beyond the scope of the current project. However, such monetary accounts could be very illustrative and useful since they provide an aggregated indicator of ecosystem asset values. Although this indicator does not indicate the 'total economic value' of ecosystems, it does provide an indication of the value of the contribution of ecosystems to consumption and production, as measured with exchange values – for the ecosystem services included in the accounts. The overall value may be of less relevance for supporting decision making, but *changes* in this value would be a relevant indicator for assessing overall developments[19].

3) Highlighting ecosystems and ecosystem services of particular concern for policy makers.
The accounts, when implemented over multiple years, clearly identify the specific ecosystem assets (e.g. the Doggersbank, the Wadden Sea), ecosystem types (e.g. estuaries or intertidal areas) and ecosystem services (e.g. marine fishing or water cleansing by benthic organisms) that are changing most significantly. For example, climate change may have a significant impact on the North Sea area affecting its ecosystems and the services they provide. In the case of negative trends, the accounts would thus provide information to determine priorities for policy interventions. Since a number of causes for ecosystem change (e.g. nutrient loads, certain economic activities taking place on the North Sea) are also incorporated in the accounts, there is baseline information to identify relevant areas of focus for effective policy responses.

[19] Similar as GDP, the key macro-economic indicator for economic policies. Total value of GDP is of less importance to policy, but changes in GDP (economic growth) all the more.

4) Monitoring the status of biodiversity and indicating specific areas or aspects of biodiversity under particular threat.

Compared to existing biodiversity monitoring systems, the accounting approach offers the scope to provide information on biodiversity in a structured, coherent and regularly updated manner. Aggregated indicators for administrative units including for countries and continental scale (e.g. Europe) provide information on trends in biodiversity as well as species or habitats of particular concern. In this context, the biodiversity account can include information on species important for ecosystem functioning (e.g. 'key-stone' species indicative of environmental quality), and species important for biodiversity conservation (e.g. the presence and/or abundance of rare, threatened and/or endemic species). Where biodiversity accounts are presented as maps of biodiversity indicators, specific areas of concern or improvement can be identified, as well as areas of particular importance for biodiversity conservation both inside and outside protected areas.

5) Quick response to information needs.

To support ongoing reporting requirements as well as providing information to support discussion of emerging issues, the accounts provide information that is:

- Comprehensive - covering ecosystem services and assets, maps and tables, physical and monetary indicators, covering a wide range of ecosystem types and services
- Structured - following the international framework of the SEEA aligned with the System of National Accounts (SNA)
- Coherent - integrating a broad range of datasets to provide information on ecosystem services and assets
- Spatially referenced – linking data to the scale of ecosystems and allowing the integration of data across difference accounts.

Ideally, accounts should be updated on a regular basis, e.g. bi-annual or annual, taking into account source data availability and user needs. As a result, a structured, comprehensive and up-to-date database would become available with which it would be possible to respond to policy demands for specific information. An integrated assessment, for example, an environmental *cost benefit analysis* of a proposed policy or, say, an assessment of new investment in infrastructure, can typically take anytime from half a year to several years. Ecosystem accounts present a ready-to-use database that can significantly shorten the time needed to address this information need. Assessment of specific policies or investments will likely require additional information beyond what is presented in the ecosystem accounts, but, in many cases, a wide range of environmental and economic impacts can be modelled through a combination of information included in the accounts and relevant additional data. Further, different assessments can be based on a common underlying information set. This allows more focus on the outputs from reviews, rather than evaluating the data inputs. This is analogous to the way in which a common, core set of economic data underpins economic modelling.

6) Monitoring the effectiveness of various policies.

The accounts are an important tool to monitor the effectiveness of various regional and environmental policies, by allowing the tracking of changes in the status of ecosystems and the services they provide over time in a spatially explicit manner. This includes the monitoring of SDG14: Life below water. In the European context, it is particularly relevant for monitoring the key targets for the Marine Directive, and on a national level, the Dutch 2030 North Sea Strategy[20]. The spatial detail of the accounts allows comparing developments in areas influenced by policies with areas with less or no influence of specific policy decisions. In particular, the notion of return on investment may be applied by assessing the extent to which expenditure on a specific program or a particular piece of regulation has made a material impact on the condition of relevant ecosystems or the flows of ecosystem services.

[20] https://www.noordzeeloket.nl/beleid/noordzee-2030/

7) Use in economic and financial decision making.
Ecosystem accounting is designed to support the use of environmental information in standard economic and financial decision making. In this context, the measurement of the value of ecosystem services in exchange values supports direct integration with standard financial and national economic accounting data. Consequently, the data can be used to extend standard economic modelling approaches and to enhance broad indicators of economic performance such as national income, savings and productivity. While these measures and applications are different from the more common applications of ecosystem services valuations, the ability to consider ecosystems through multiple analytical lenses appears a strong motivation to continue development of valuations for accounting purposes.

7. Recommendations for further extensions and improvements

In this section we present the main recommendations for a further extension and improvement of the various ecosystem accounts for the Dutch part of the North Sea.

7.1 Ecosystem types and extent account

- The ecosystem typology developed and used in this study should be evaluated with key national stakeholders.
- The ecosystem typology may be extended to include known occurrences of non-mobile biota, such as oyster and mussel banks, reefs, sea grass meadows etc.
- The ecosystem typology should be cross walked with international classification systems like the IUCN RLE and EUNIS classification to enable international comparability of the data.
- In this study, the geographical scope of the marine account includes only pure marine ecosystem types, excluding coastal ecosystem types like beaches, dunes and coastal wetlands. The first international guidelines for marine accounts recommend to include also coastal ecosystem types, so maybe the chosen scope has to be reconsidered[21].

7.2 Condition account

- Further work is needed to evaluate which indicators are most useful for the condition account, which indicators could be omitted in a future update, and which policy relevant indicators are still missing. The MSFD monitoring was taken as a starting point, but could be expended with some additional policy relevant indictors.
- The North Sea is probably one of the most extensively monitored marine areas in the world. However, this does not mean that all data are readily available to be included in the condition account. For example, for some indicators, the spatial distribution of the data is not available, but only one average number for the entire DCS.
- The data portal 'informatiehuis marien' has been developed to make marine data publicly available[22]. This data portal contains a lot of information; however, data is often not available in the right GIS format. Also, meta data is often missing precluding the right interpretation of the indicator. Finally, many of the KRM indicators are not (yet) included in the data portal.
- The coverage for the Dutch Wadden Sea for this study was, as yet, insufficient. As a consequence of that, this part of the research area is not covered very well, sometimes resulting in an over- or underestimation of the indicator for this area. It is recommended to separately investigate and improve data coverage for the Wadden Sea.
- An important part of the policy applications stems from having the condition account for multiple years. Developing time series for the indicators would further improve the strength of having all data presented in one consistent framework.
- A reference level is a value against which it is meaningful to compare the current value of a variable in order to derive an indicator. Reference levels can be baselines, standards, thresholds, limits or benchmarks, and may refer to either or both an upper or lower level of the range of a condition variable.

[21] https://www.oceanaccounts.org/technical-guidance-on-ocean-accounting-2/
[22] https://www.informatiehuismarien.nl/uk/

For the marine part of the North Sea, reference levels can be based on the targets set for the Marine Directive[23].

- Many of the current indicators are presented as individual metrics. As a result the condition account is a large table with many measures. Visualization of the results could be further improved to bridge the gap between a big table with a lot of data and the key aspects that policymakers need to know.
- In quite a few cases only information about a mean value is available (for example sea water temperature). Given the significance of extreme values, it is recommended to also include information on variability.

7.3 Ecosystem services account

Overall

- Time series should be developed for the physical ecosystem service accounts as these would allow to evaluate the changes in the supply of ecosystem services over time.
- Special attention should be paid to ecosystem services that are concentrated near the marine–land intersection (i.e., the coastal zone), such as flood protection, nature related recreation and tourism etc. Eventually, the ecosystem accounts for the terrestrial and marine environment should be fully integrated.

Scope of the ecosystem services

- The DCS produces important regulating and maintenance services, including waste mediation, carbon sequestration and flood protection. Spatial explicit models should be developed for these services and included in a future update of the NCA.
- Extraction of oil and gas from the DCS does not represent a contribution by the marine ecosystem and thus should not be included as an ecosystem service in the NCA.
- The use of space should be included as an ecosystem service, but only if the use is directly related to the intrinsic and ongoing nature of the ecosystem(s). Further investigation is needed for what specific uses this applies.

Spatial allocation

- Overall, the spatial data availability for all ecosystem services investigated in this study needs to be further improved.
- In particular, the spatial allocation of marine fishing should be further improved using additional data sources. For demersal fish a more detailed allocation to ecosystem types is needed than for pelagic fish.
- The spatial allocation of nature related tourism and recreation needs further consideration. Beach tourism and recreation clearly can directly be related to the coastal – marine ecosystems, however as yet it is not clear how the allocation to the different ecosystems, i.e. dunes / beaches / seas etc. should be done. Experimental work using mobile phone location data might be considered a valuable source of information.

7.4 Possible extension of the accounts

Monetary supply and use tables for ecosystem services.

As a next step, monetary supply and use tables could be developed for the North Sea. These tables would show the contribution of marine ecosystems to the economy in monetary terms. Based on the physical supply and use tables experimental monetary values could be calculated for the different ecosystem services using different valuation techniques. The valuation techniques to be selected should generate outcomes that are consistent

[23] https://www.noordzeeloket.nl/publish/pages/158924/marine_strategy_part_1_main_document_2018_-_2024.pdf

with the National accounts. There is a list of methodologies that potentially can be applied for the valuation of ecosystem services (see SEEA EEA (2014) and SEEA EEA technical recommendations (2018)). In the second half of 2019 Statistics Netherlands and Wageningen University will publish the monetary ecosystem accounts for the terrestrial environment of the Netherlands. Based on this experience also the valuation of ecosystem services for the marine environment could be undertaken.

Monetary asset account
The asset account records the monetary value of the opening and closing stocks of all ecosystem assets within an ecosystem accounting area, and presents the additions and reductions in those stocks. In most cases, monetary values of assets are estimated based on the net present value (NPV) of the expected future flows of all ecosystem services generated by an ecosystem asset. This requires an understanding of the likely pattern for the supply and use of each ecosystem service and recognition that the pattern of supply among different ecosystem services from a single ecosystem asset is likely to be correlated. In principle, the asset account will show the 'total' value of the ecosystem assets: the value of the natural capital of the Dutch part of the North Sea. As is the case with GDP as indicator for economic growth, it is not the absolute number that policy makers are primarily interested in, but in the development of this indicator over time. This however requires time series analyses.

Environmental pressure account
A pressure account is not part of the SEEA EEA core accounts, but is highly policy relevant as it reveals how nature is impacted by economic and social pressures. It basically shows where the key pressures on the ecosystems originate (i.e. different industries households, rest of the world) and on what ecosystems these pressures have the greatest impact.

Biodiversity account
Another option is to develop a biodiversity account for the North Sea. In the second half of 2019 the first experimental Biodiversity account for the terrestrial part of the Netherlands will be published. Based on the outcome and conclusions of this report, spatial data availability and user needs, a biodiversity account for the North Sea could be considered. With regard to the compilation of marine biodiversity accounts, the same approach as currently undertaken for the terrestrial Netherlands could be used, which also has a part of the marine area and its ecosystems included (i.e. Wadden Sea), and add the marine accounts to it. In the current biodiversity account, and the underlying data sources, only two aquatic ecosystems are distinguished: salt and fresh water. We think of a further break down of these ecosystems, for instance into coastal greshwaterwetlands, salt marshes and North Sea, but alternative break downs are possible, for example a distribution following habitats with biodiversity hotspots (For options, see for example: Imares WUR (2011).

8. Conclusions

In this study we have compiled the first experimental physical ecosystem accounts for the Dutch part of the North Sea based on the SEEA EEA framework. The general conclusion is that it is feasible to compile natural capital accounts, not only for terrestrial ecosystems but also for marine ecosystems. Based on readily available data it was possible to compile the extent, condition and the physical ecosystem service account. However, in this pilot project we were able to include only a limited number of condition indicators and ecosystem services.

The North Sea is probably one of the most extensively monitored marine areas in the world. We found that many different data sources on ecological, economic and other topics are collected and made available by many different institutes. Although there are several ongoing initiatives, such as data portal ‘informatiehuis marien’, the to bring these data together in a centralised data system, what is still lacking is an overall data framework to integrate and analyse all this data in a coherent and consistent way for policy purposes. This is where the SEEA EEA accounts can play a key role by providing a standardised statistical approach to organise existing data from many different data sources. As the SEEA EEA accounts are embedded in the statistical system, data from the accounts can be directly be combined and compared with many other statistical data sources, in particular the macro- economic data from the National accounts. Furthermore, all data in the ecosystem accounts is spatially explicit, allowing the data to be used for spatial analysis and planning.

The scope of the condition account and physical supply and use account could be further extended in the future, making the data more relevant for users. New accounts that could be developed are the monetary supply and use tables, the monetary asset account, a biodiversity account and accounts for environmental pressures. Important challenges remain, particularly with regard to data availability, the compilation of time series and the allocation of ecosystem services to ecosystems.

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Annex 1: metadata condition indicators

Indicator	Main group	Year	Source	Explanation for indicator choice
PCB	Pollutants	2015-2016	RWS	PCB is a chemical pollutant, particularly persistent in the organic and sediment fraction and it is toxic for marine life. Recent spatial data were available on a relatively small scale compared to similar potential indicators.*
Lead	Pollutants	2014-2016	Emodnet	Lead is a toxic pollutant. Recent spatial data were available on a suitable scale for the entire area.
Tributyltin	Pollutants	2015-2016	RWS	TBT is a common pollutant in marine environments, toxic for marine life. Recent spatial data were available on a small scale for the entire area.
Phosphate	Eutrophication/ food web	1972-2013	Emodnet	Phosphate is a limiting nutrient and in abundance causes eutrophication, thus being a suitable indicator of marine ecosystems. Relatively recent spatial data were available on a small scale for the entire area.
Inorganic N	Eutrophication/ food web	2016	RWS	Inorganic N is an important indicator for water quality. Suitable spatial data were available on a small scale for the entire area.
Phaeocystis (phytoplakton)	Eutrophication/ food web	2016	RWS	Phytoplankton as indicator of marine eutrophication. Suitable spatial data were available on a small scale for the entire area.
Chlorophyll a	Eutrophication/ food web	2016	RWS	Chlorophyll A concentration is an indicator of the biomass in marine waters and thus are a measure of trophic status. Recent spatial data were available on a small scale for the entire area.
Benthos	Benthos	2015-2016	RWS	Benthic indicators are used to qualify the environmental condition of the sediment. Recent spatial data were available on a small scale for the entire area.
Salinity	Water characteristics	2016	RWS	Salinity indicates the type of marine ecosystem. Recent spatial data are available on a small scale for the entire area.
O2 dissolved	Water characteristics	2014	Emodnet	Dissolved oxygen is a limiting factor for marine life. Recent spatial data was available on a small scale for the entire area.
Benthic fishing intensity	Fish	2011-2015	RWS	Only available spatial indicator considering amount of fish in the research area.

* Often the choice of use of certain variables was limited by those of which datasets were available at all, as well as on spatial scale that covered the entire North Sea with sufficient measuring points, and was of recent date.