Comparing methods to approach cumulative effects in the North-East Atlantic: CUMULEO case study

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Summary

OSPAR Intersessional Correspondence Group – Cumulative Effects (ICG-C), part of OSPAR commission Environmental Impact of Human Activities (EIHA), is seeking for common approaches on (cross-border) cumulative effects. At the OSPAR ICG-C meeting of 12-13 December 2012 (Copenhagen), three cumulative effects assessment (CEA) methods have been discussed: CUMULEO; ODEMM; and HARMONY. It was concluded that a case study could help in finding best available approaches and tools within the three methods for a specific question. This report describes the case study based on the CUMULEO method.

The following elements are included in the CEA:
Activities

- Offshore Wind Parks (OWP)
- Fisheries (beam trawls, otter trawls and pelagic trawls)

Pressures

- Underwater noise (causing avoidance of the affected area by sea mammals and fish)
- Presence of offshore structure (causing avoidance of the affected area by birds to prevent collision)
- Sealing (change of seafloor habitat from sediment to hard substrate, causing habitat loss for local benthos)
- Abrasion (physical damage to seafloor habitat, causing reduction in benthic biomass)
- Extraction of species (selective extraction of commercial fish, bycatch of non-target fish and marine mammals)

Ecosystem components

- Birds
- Benthos
- Marine mammals
- Fish

The five pressures are all leading to habitat loss, i.e. area no longer suitable as habitat for the different ecosystem components. Therefore, the endpoint used for the CEA is habitat loss. For OWP 100% loss (impact severity = 1) is assumed within the affected area (impact distance from the OWP (m)). For fisheries the loss is assessed as a fraction, depending on the pressure-ecosystem component combination. The affected area is determined by the fishing intensity. In summary, the impact is calculated as "Impact = impact severity * affected area".

Based on the results of this case study, it can be concluded that the cumulative effects of offshore wind farm development in the southern North Sea, according to the ambitions of the involved countries, cause a habitat loss of 77, 115 and 151 km^2 in the year 2020, 2030 and 2050, respectively.

The cumulative (combined) ecological effects of fisheries is considerably larger than that of OWP development amounting to 13% and 0.03% of the southern North Sea study area, respectively.

1 Introduction

OSPAR Intersessional Correspondence Group – Cumulative Effects (ICG-C), part of OSPAR commission Environmental Impact of Human Activities (EIHA), is seeking for common approaches on (cross-border) cumulative effects. At the OSPAR ICG-C meeting of 12-13 December 2012 (Copenhagen), three cumulative effects assessment (CEA) methods have been discussed:

i. The HARMONY project, which was designed to provide a harmonised and optimised approach in assessing the Baltic Sea biodiversity and nature conservation status in the context of the pressures exerted, see http://harmony.dmu.dk/;
ii. CUMULEO a research project by IMARES, which is investigating a methodology for scaling human pressures to population level impacts in the marine environment, see http://content.alterra.wur.nl/Webdocs/WOT/Papers/WOTpaper_14.pdf;
iii. ODEMM (Options for Delivering Ecosystem-Based Marine Management), see http://www.liv.ac.uk/odemm/ and in particular work package 5 which includes work to map pressures and investigate combined and cumulative effects.

It was concluded that a case study could help in finding best available approaches and tools within the three methods for a specific question.

The focus of the case study is CEA in Marine Spatial Planning (MSP) (OSPAR, 2013). In the process of MSP forecasting can be used to predict the possible impacts of plans or projects on the ecosystem, for which CEA is a useful tool. The case study should be seen as an experiment to elucidate which of the three identified tools are useful (and under what conditions) at a scale, relevant for cooperation of OSPAR Parties in a MSP setting. The experimental question to test the approaches is (OSPAR, 2013): *What are the cumulative effects of offshore wind farm development*[1] *in the southern North Sea according to the ambitions of the involved countries for the coming 15 years?* This question is a preparation for possible assumed management decisions on the need for cooperation with authorities from bordering countries.

Elaboration of the question (OSPAR, 2013):

- Temporal: Based on the experimental question on the effects of wind farm development for the coming 15 years (as mentioned above), the assessment will take into account the development of wind parks up to the year 2030. As the expected life time of a wind park is 20 years, the effects of the developed wind parks from 2015 to 2030 should be assessed for the period 2015-2050. It is noted that within this timeframe the decommissioning of existing wind parks is likely to start, however, given uncertainties in how this will be undertaken and whether or not existing sites will be redeveloped, decommissioning will be incorporated in the case study as a consideration rather than a direct output.
- Spatial: The study area is the southern North Sea from the border between the Belgium and French continental shelf in the south, the border between Danish, Norwegian and Swedish

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1 As an elaboration of EU policy, North Sea countries have a high ambition to develop offshore wind farms (OWF) in the coming decades. At this moment we do not know if this development, in any stage, will have significant effects on marine ecological quality. In a quick scan with Dutch experts Rijkswaterstaat (the Netherlands) it was estimated with a realistic maximum scenario of OWF that there might be effects and that there is common ground for North Sea countries to further elaborate the outcome of the quick scan. Rijkswaterstaat wants to deepen and widen the results; deepening with a more scientific approach and broaden by cooperating with other countries.

waters in the East and from the English /Scottish border as the Northern Border. In this area we find a substantial development of offshore wind farms in the coming years.

- Activities and developments taken into account: For the experiment it is useful to take more than one activity into account. Different types of fishing activities (and whether or not these are excluded within wind farms) can be included in the assessment as a second activity, to test in the experiment and is logically connected to the main question. The effects from other activities and climate change on species that are most likely to be affected by these connected activities should be described briefly.

The prime motivation for using offshore wind farm and different fishing activities in the first instance to test the three approaches is the large spatial area that both activities (potentially) occupy in the southern North Sea.

The primary goal of this study is to perform a case study on CEA as described above with the CUMULEO-methodology. The purpose is to contribute to a process running within OSPAR on the selection and/or need for further development of CEA, by performing this case study on the same footing (datasets used, reporting format) as two related case studies with different methodologies (ODEMM by CEFAS, the UK, in 2013; HARMONY by AU/DMU, Denmark, in 2013). A longer term goal for the OSPAR ICG-C is to identify a common approach on CEA. As stated above this case study is an experiment to identify the applicability of the three identified tools in an envisioned MSP setting. The case study can contribute to that long term goal by:

1. Developing recommendations for a common approach in CEA for OSPAR–ICG-C;
2. Estimating possible cumulative effects on the offshore wind farm development up to 2030 for a selection of species, noting that such outputs will be indicative (i.e. not a definitive valuation of cumulative effects of offshore wind farm development);
3. Defining the appropriate level of detail in estimating the effects (including prioritizing) needed for the assumed management decisions.

2 General CUMULEO approach

2.1 Introduction to the CUMULEO approach

OSPAR ICG- C defines CEA as follows (OSPAR, 2013): “Cumulative effects assessment is a systematic procedure for identifying and evaluating the significance of effects from multiple pressures or activities. The analysis of the causes, pathways and consequences of these effects is an essential part of the process.” As with environmental assessments in general, there is not one approach or methodology for all assessments of cumulative environmental effects (Karman & Jongbloed, 2008). Different circumstances, such as the location of a project and the type of potential environmental effects will dictate appropriate methodologies. A great challenge in cumulative effects assessment (CEA) is recognizing and predicting the numerous interactions and (indirect) effects. Modelling, expert systems and geographic information systems are being increasingly used. However, where information is lacking, qualitative approaches and best professional judgement are used. It is obvious that the qualitative methods provide results for which it is more difficult to evaluate the significance and acceptability. This section describes our general approach to CEA, together with approaches and examples from available literature.

The basic approach of CUMULEO is schematically represented in Figure 1. It assumes that effects are a function of the intensity of pressures caused by activities and the sensitivity of ecosystem components to those pressures. Each activity can cause several types of pressure: for example: trawl fishery causes both abrasion and visual disturbance. Each pressure in turn can affect multiple but not necessarily all ecosystem components: for instance visual disturbance will affect birds, but will not affect cockles. A stepwise approach, adapted from Van der Walt (2005) and Therivel & Ross (2007), is used for the CEA:

1. Scoping phase
    a. Define spatial and temporal boundaries
    b. Identify ecosystem components, pressures and activities
2. Assessment phase
    a. Describe intensity of activities
    b. Assess intensity of pressures
    c. Describe sensitivity of ecosystem components
    d. Assess cumulative effects

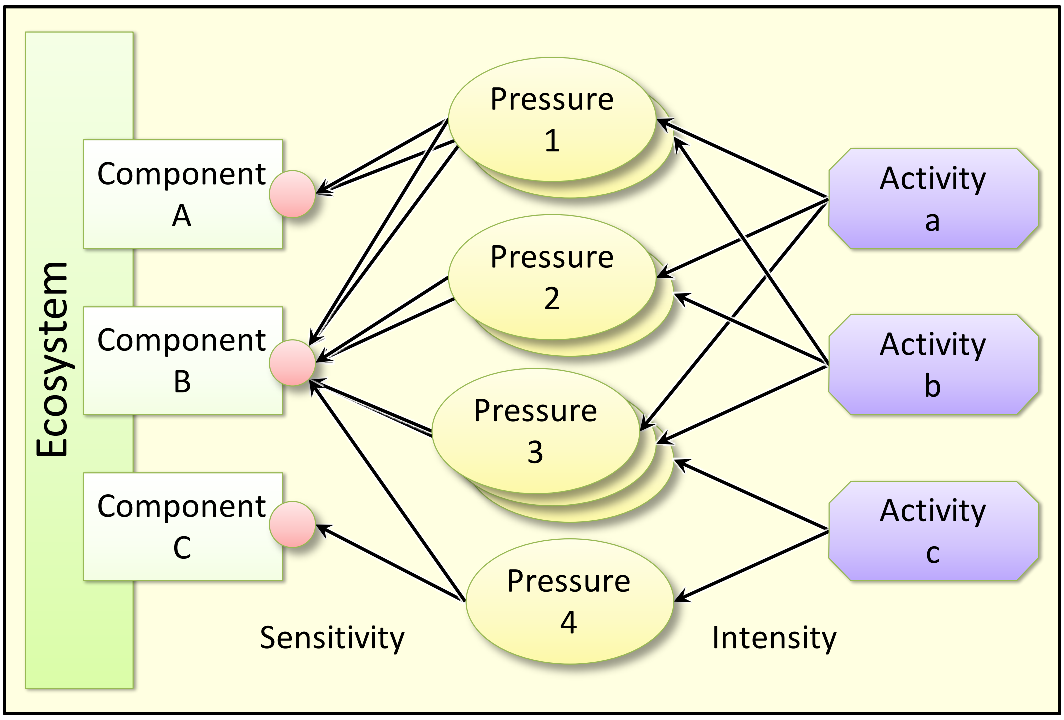

Figure 1 A generic outline of cumulative effect assessment (CEA) in which relationships between activities, pressures and ecosystem components/indicators need to be elucidated (Karman & Jongbloed, 2008).

2.2 Scoping

Following the general stepwise approach (Van der Walt, 2005; Therivel & Ross, 2007), the first step of the assessment is scoping. It is used to determine the range and extent required for CEA. Scoping includes the identification of the ecosystem components, pressures and activities. Most often used instruments in the scoping process are consultations and questionnaires, matrices, spatial analysis and expert opinion (Johnston & Walker, 1999; Karman & Jongbloed, 2008). It is important to consider that much of the confusion in classifying, defining, assessing and managing cumulative effects is due to poorly defining the resources of concern and the spatial and temporal scales of the analysis (MacDonald, 2000). “Scoping” is therefore an important aspect of CEA. The scope of the CEA depends on the level of the assessment. Strategic assessments, early in the process, should have a broad scope whereas later and more specific assessment should be more focused on the relevant issues.

First, the spatial and temporal boundaries are defined, i.e. the area and time frame of concern. Next, the ecosystem components, pressures and activities are identified. These elements are identified in such a way that the framework enables linking (manageable) human activities with the pressures and (potential) effects they cause in the marine ecosystem.

For administrative purposes it is important to have a good overview of activities that should (or could) be subject to a cumulative effects assessment. An extensive overview of activities is provided in the EU EIA Directive (EC, 1997), taken over in the Kiev Protocol to the Espoo Convention. Pressures can be selected from existing lists, such as Annex II from the European Marine Strategy Directive (EC, 2008) and adapted to regional specifications.

Ecosystem components or indicators have a prominent and legitimate role in monitoring, assessing, and understanding ecosystem status, impacts of human activities and effectiveness of management measures in achieving objectives. Given all these roles, the suites of indicators intended to fulfil them must be chosen with care. Rice & Rochet (2005) presented a framework for selecting a suite of indicators from the long list of diverse, potential indicators. Although intended for fisheries management, the framework has a wider applicability and can be used for selection of indicators for ecosystem management. Ecosystem components can also be based on (inter)national policy objectives, such as e.g. the European Natura 2000 network or the Marine Strategy Framework Directive.

A well performed scoping process should lead to information that can be represented schematically according to Figure 1. The basic elements (ecosystem indicators, impacts and activities) are now identified and related to each other. No information is provided in the scoping process with regard to the intensity of the impacts or with regard to the sensitivity of the indicators for the selected impacts.

Although now the basic elements of CEA, i.e. activities – pressures – ecosystem components are identified, it does not show the elements of space and time in which effects can cumulate (MacDonald, 2000).

The element of time can be disregarded in the assessment by assuming all elements are present at the same time. This can be considered as a worst case, conservative approach. Depending on the available information and the goal of the CEA, temporal distribution can be implemented, e.g. by including seasonal differences.

A simple approach to include spatial dimension in the CEA is described by Halpern et al. (2008). They mapped the intensity of pressures in geographic cells and included whether or not a specific ecosystem was present (0 or 1). Instead of using this binary 'yes' or 'no' approach, a more refined approach is also possible. The assessment could also include the probability of pressures and ecosystem components being present, as implemented by Zacharias & Gregr (2005) for example.

2.3 Assessment

In the assessment phase, two stages can be distinguished: describing and assessing intensity of activity and describing and assessing the sensitivity of ecosystem components for the different pressures (Figure 1). Once both the intensity of impacts and the sensitivity of the ecosystem indicators are known, the actual cumulative effects analysis can be carried out.

2.3.1 From activity to pressure

Information on the activities is collected for CEA in order to quantify the intensity of the pressures caused by the activities. Such information is usually available in a project CEA, but often limited and scattered available for a management CEA. The intensity of pressures is then usually assessed based on the intensity of related activities.

2.3.2 From pressure to ecosystem component

The sensitivity of ecosystem components can be described in various ways, either qualitative (e.g. Connor (2008), Robinson et al. (2008)) or (semi-)quantitative (e.g. Zacharias & Gregr (2005), Hiddink et al. (2007)). This sensitivity should be specific for the type of effect that is considered of interest for the assessment (e.g., mortality, reduced feeding efficiency or evasive behaviour). Sparse data sets and system complexity have compelled conservation scientists to estimate data through expert judgment and other scoring, ranking, and rating procedures (Wolman, 2006). Qualitative and semi-quantitative methods thus mostly rely on expert judgement to classify the sensitivity of ecosystem components to specific pressures. A quantitative method is to use dose-response relationships (Jak et al., 2000; Karman et al., 2009).

To combine all individual effects, similar endpoints should be used. In case the CEA is not based on one uniform endpoint, e.g. mortality, an additional step should be included in the assessment to derive one single endpoint. Jak et al. (2000) and Karman et al. (2009) describe a method to integrate the effects of potential exposures. They combined mortality with reproduction to derive a single population measure. As a final step all effects are combined to assess the cumulative effects.

3 Case study methodology

3.1 Scoping

3.1.1 Study aim and requirements

The initial geographical scope and ambition level for the three comparative case studies have been based on the discussions with the ICG-C (Copenhagen, December 2012) and an OSPAR EIHA meeting (Ghent, April 2013). The main issues determining the scope of the case study are:

- Case study topics:
  North Sea, focusing in Offshore Wind Energy, Fisheries and Ecology. Optionally the inclusion of marine protected areas (MPA) has been considered. The assessment should include a selection of species.
- Study area:
  Dutch EEZ + Adjoining area of English waters possibly also including the German en Danish EEZ in as far as these overlap with the area covered by the WINDSPEED-database. The study area is the southern North Sea from the border between the Belgium and French continental shelf in the south, the border between Danish, Norwegian and Swedish waters in the East and from the English /Scottish border as the Northern Border.
- It is noted that outputs of the case study should be indicative, i.e. not a definitive valuation of cumulative effects.

This means that the case study should include the effects of offshore wind parks (OWP) and fisheries on a selection of species and may include MPA. There is thus no need to strive for a complete assessment in terms of ecology and anthropogenic influences. Furthermore, since it is noted that outputs will be indicative, there is no need to strive for an accurate quantitative estimate of absolute impact from OWP and fisheries on the southern North Sea ecosystem. The focus of this case study will therefore be more on being robust and transparent, rather than being detailed and complete. This approach has been taken into account for the selection of activities, pressures and ecosystem components, as well as for the assessment of the relationships between these elements.

Datasets used for the case study were selected primarily based on (ready) availability and with a focus on comparison with two other CEA-methodologies. The selected datasets therefore needed to be such that sharing with the other parties was possible. The selected datasets are thus no longer current at the time the case studies were performed, but are suitable for the purpose of comparing the methods.
The dataset collated for the WINDSPEED-project (www.windspeed.eu; Schillings et al. (2011, 2012); Van der Wal et al. (2011); Jongbloed et al. (2014)) was used as a basis for the case study. The sources of data for the WINDSPEED project are listed in Appendix B.

The selected elements are discussed in the sections below. The data (sources) used for the case study are discussed in the assessment section (see page 13).

3.1.2 Activities

Activities that are included in the case study are OWP and fisheries.

For OWP, several stages of development have been addressed: operational phase; construction phase; authorised, i.e. license granted; application for a license; 'development, i.e. preparing for an application; and proposed, i.e. area proposed for offshore wind energy (OWE) development. It should be noted that the effect assessment is based on the operational phase, regardless of the current stage of development, i.e. all OWE have been assessed as if the operational phase has been reached. The effects caused during construction have not been included, nor have those that could occur during decommissioning.

For fisheries, all types of fisheries that use hauling nets within the southern North Sea have been included. These are mainly vessels operating with engine sizes over 300 hp and using beam trawls, otter trawls and pelagic trawls.

3.1.3 Pressures

No specific requirements were made considering the pressures that should be included in the case study. Taking into account the focus of this case study (i.e. robustness and transparency, instead of details and completeness), the main pressures caused by OWP and fisheries were considered. These are:

- OWP:
    - Underwater noise (causing avoidance of the affected area by marine mammals and fish);
    - Presence of offshore structure (causing avoidance of the affected area by birds to prevent collision);
    - Sealing (change of seafloor habitat from sediment to hard substrate, causing habitat loss for local benthos);
- Fisheries:
    - Abrasion (physical damage to seafloor habitat from towed/mobile fishing gear, causing reduction in benthic biomass);
    - Extraction of species (selective extraction of commercial fish species and bycatch of non-target fish and marine mammals).

Assessment of each pressure separately will require more effort than combined assessment. Since an estimate of the effects of individual pressures is not the aim of the study, these pressures are all assessed based on a general endpoint: habitat loss/change. The five pressures are all leading to a loss of suitable habitat, i.e. area no longer suitable as habitat for the different ecosystem components.

3.1.4 Ecosystem components

As for the pressures, no specific requirements were made considering the ecosystem components except for the note that a selection of species should be included in the case study. Taking into account the focus of this case study (i.e. robustness and transparency, instead of details and completeness), the following ecosystem components were selected:

- Benthos
- Birds
- Fish
- Marine mammals

3.1.5 Scoping results

The result of the scoping process is presented schematically according to

Figure 2. The basic elements (ecosystem indicators, pressures and activities) are now identified and related to each other. The next section (assessment), describes the assessment of the elements and their relationships.

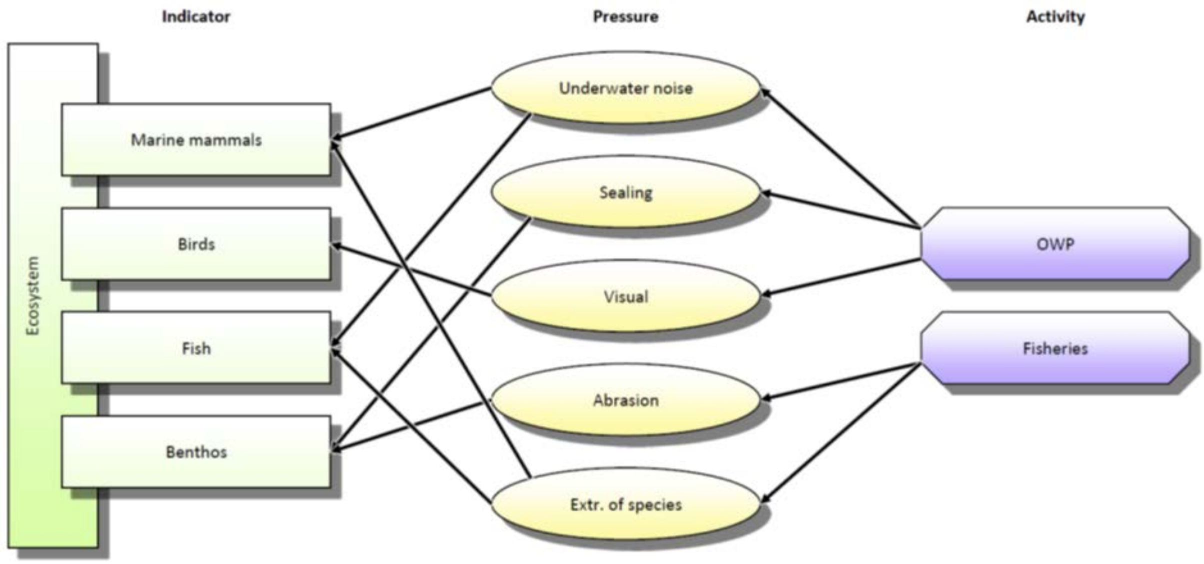

Figure 2 Basic elements of the case study.

3.2 Assessment

3.2.1 From activity to pressure

To assess the combined pressure of human activities, maps showing the location of each activity were collected or in some cases constructed.

3.2.1.1 OWP

The data on OWP as used for this case study with CUMULEO was originally collated by the WINDSPEED-project during the years that the project was performed (2007-2011). National datasets of the adjoining countries were collected existing OWP, known development as well as expected future development. For known as well as development the near future applications for licenses to develop Offshore Wind Energy (OWE) to the competent national authorities have been screened. For expected development the more distant future national development plans were considered. Some of the data has been taken from datasets provided by OSPAR.
As the WINDSPEED dataset represents the period 2007-2011, an updated dataset has been created using a variety of sources, including Crown Estate, OSPAR and the 4C Offshore Wind Farm website. In case of conflicting information, cross-checks were made with information from websites of national regulators and individual projects. The present datasets is up-to-date for December 2013, with added new proposed wind farms and refreshed data on the status, no. of wind turbines and installed capacity (planned and or realised). This updated WINDSPEED-dataset is shown in Figure 3. Some of the statistics are given in Table 1 which gives an overview by country, status and the timing of development for the amount of area taken up by OWE development and Table 2 which uses the same breakdown but focusses on the number of turbines and the installed capacities (MWs).

Additional information on the original WINDSPEED OWP datasets can be found in Schillings et al. (2011).

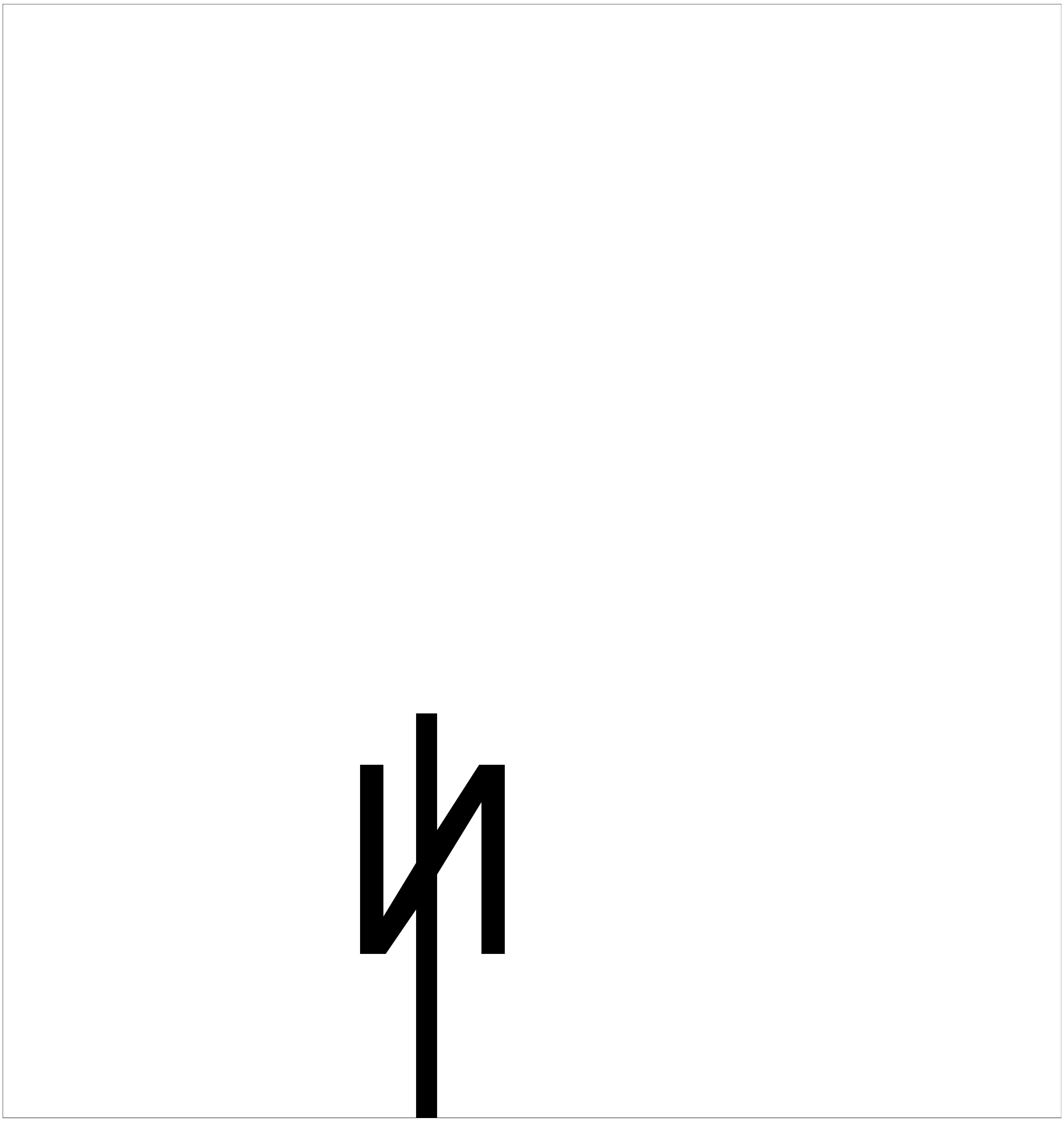

Figure 3 Map showing the different development stages of Offshore Wind Energy in the study area (southern North Sea). A few wind park developments have been refused (by the authorities) or cancelled (by the developer). The darkest colours are for the earliest occurrences, with progressively lighter colours for developments that is expected to occur in the (more distant) future.

Table 1 Area (km^2) in use or projected to be used by OWE developments within the study area, broken down by country (columns), status and timing of development (rows). The area marked as 'non OWP' reflects the part of the study area that is not used for (or planned as) OWE

	BE	DE	DK	NL	NO	UK
Operational						
2012 and earlier	37.5	6.25	62.5	68.75	0	143.75
2013-2020	18.75	62.5	0	0	0	362.5
Construction						
2013-2020	6.25	362.5	0	0	0	25
Authorised						
2013-2020	100	918.75	0	425	0	750
2020-2030	0	68.75	0	0	0	0
Application						
2013-2020	0	237.5	0	0	37.5	2218.75
2020-2030	0	1425	0	0	0	293.75
2030-2050	0	231.25	0	12.5	0	0
Proposed						
2013-2020	37.5	18.75	243.75	1225	0	68.75
2020-2030	0	143.75	443.75	1062.5	0	12887.5
2030-2050	0	2018.75	0	6.25	0	3631.25
Development						
2013-2020	0	212.5	0	0	0	1956.25
2020-2030	0	506.25	0	0	0	312.5
2030-2050	0	737.5	0	0	0	1631.25
Cancelled						
2012 and earlier	0	225	600	25	0	93.75
Refused	0	0	0	0	0	0
2012 and earlier	0	0	0	43.75	0	0
non OWP						
remaining	3268.75	34162.5	56906.25	61493.75	85518.75	170168.75
Total	3468.8	41337.5	58256.3	64362.5	85556.3	194543.8

Table 2 OWE development number of turbines and MegaWatts installed capacity in the study area, broken down by country, status and timing of development ('oper.': operational; 'constr.': construction; 'auth.': authorised, i.e. license granted; 'applic.': application for a license; 'devel.': development, i.e. preparing for an application; 'prop.': proposed).

		pre-2013		2013-2020		2020-2030		2030-2050	
		no. of turbines	MW capac.	no. of turbines	MW capac.	no. of turbines	MW capac.	no. of turbines	MW capac.
BE	Oper.	110	330	54	318	0	0	0	0
	Constr.	0	0	72	252	0	0	0	0
	Auth.	0	0	141	794	0	0	0	0
	Applic.	0	0	0	0	0	0	0	0
	Devel.	0	0	0	0	0	0	0	0
	Prop.	0	0	93	465	0	0	0	0
DK	Oper.	178	375	0	0	0	0	0	0
	Constr.	0	0	0	0	0	0	0	0
	Auth.	0	0	0	0	0	0	0	0
	Applic.	0	0	0	0	0	0	0	0
	Devel.	0	0	0	0	0	0	0	0
	Prop.	0	0	80	400	80	400	0	0
DE	Oper.	12	60	80	400	0	0	0	0
	Constr.	0	0	516	2144	0	0	0	0
	Auth.	0	0	1295	6291	83	580	0	0
	Applic.	0	0	448	2395	1753	9290	320	1600
	Devel.	0	0	240	1200	635	3483	745	4310
	Prop.	0	0	40	320	160	800	2128	13536
NL	Oper.	96	228	0	0	0	0	0	0
	Constr.	0	0	0	0	0	0	0	0
	Auth.	0	0	815	3359	0	0	0	0
	Applic.	0	0	0	0	0	0	0	0
	Devel.	0	0	0	0	0	0	0	0
	Prop.	0	0	1580	7900	400	2000	0	0
NO	Oper.	0	0	0	0	0	0	0	0
	Constr.	0	0	0	0	0	0	0	0
	Auth.	0	0	0	0	0	0	0	0
	Applic.	0	0	40	200	0	0	0	0
	Devel.	0	0	0	0	0	0	0	0
	Prop.	0	0	0	0	0	0	0	0
UK	Oper.	354	1148	429	1478	0	0	0	0
	Constr.	0	0	73	219	0	0	0	0
	Auth.	0	0	700	3205	0	0	0	0
	Applic.	0	0	1293	6700	192	738	0	0
	Devel.	0	0	1906	4136	100	500	600	3600

		pre-2013		2013-2020		2020-2030		2030-2050	
		no. of turbines	MW capac.	no. of turbines	MW capac.	no. of turbines	MW capac.	no. of turbines	MW capac.
	Prop.	0	0	5	30	1643	8215	747	3562
Total	Oper.	750	2141	563	2196	0	0	0	0
	Constr.	0	0	661	2615	0	0	0	0
	Auth.	0	0	2951	13649	83	580	0	0
	Applic.	0	0	1781	9295	1945	10028	320	1600
	Devel.	0	0	2146	5336	735	3983	1345	7910
	Prop.	0	0	1798	9115	2283	11415	2875	17098

In Figure 4 the intensity of the existing OWE parks as well as that of the expected future development is shown.

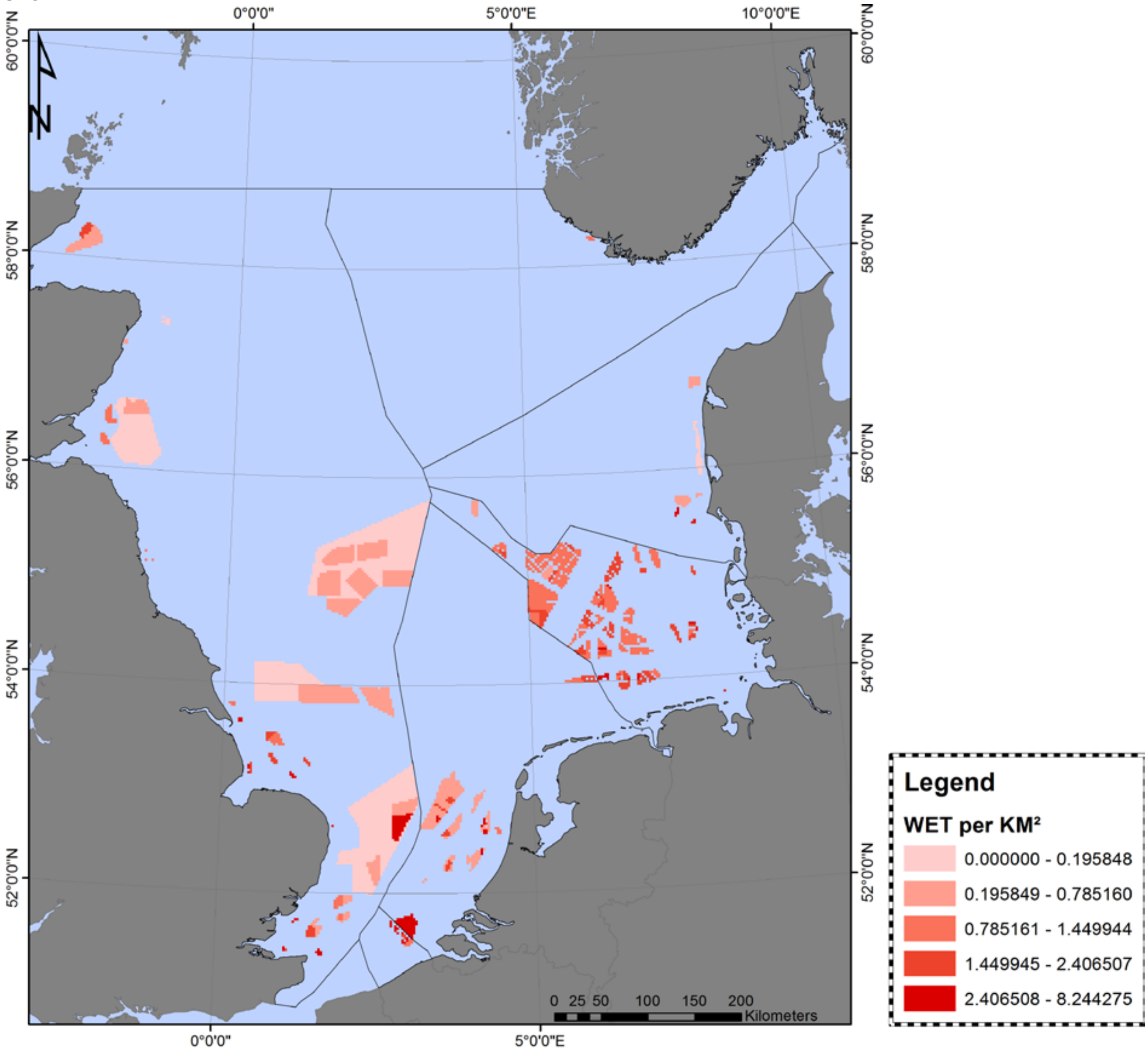

Figure 4 Density of OWE-development expressed as Wind Energy Turbines (WET) per square kilometre (km^2).

The disturbed area by OWP is assumed to be the presence of the wind park including a zone around the park. The size of the zone is determined by the disturbance distance. For the calculation of the area of habitat loss due to the presence of an OWE park the density of wind turbines for each wind park in the dataset was determined. Where a known number of turbines was available that number was used, otherwise this was estimated from an expected capacity for that location (always available) and the given capacity of the proposed type of turbine. In cases where no data was available on the proposed turbines a default value of 5 MW per turbine was used. The data used to quantify the presence of OWP is presented in Table 1 and Table 2.

The selected disturbance distances for ecosystem components used in this study have been limited to just two different values in the range of values reported in several literature sources. These choices will be elaborated next.. These values are summarised in Table 3.

Table 3 Disturbed area (i.e. habitat loss caused by underwater noise, presence of offshore structures and sealing) by OWP.

Pressure / impact	**Disturbance distance (m)**
Underwater noise, causing avoidance of the affected area by marine mammals	300
Underwater noise, causing avoidance of the affected area by fish	30
Presence of offshore structure, causing avoidance of the affected area by birds to prevent collision	300
Sealing; change of seafloor habitat from sediment to hard substrate, causing habitat loss for local benthos	30

3.2.1.2 Fisheries

For the data on fisheries effort, the WINDSPEED fisheries database is used, originating from a database with Vessel Monitoring System (VMS) records, which expresses the fishery effort as days at sea per ICES rectangle. IMARES requested and received information on fishery effort at this level of detail from national fisheries research institutes for a selection of fishery types. The types of fisheries were selected based on the perceived difficulty of combining these types of fisheries in the same area as wind turbines. Consideration where amongst others the risk of snagging trawled gears on foundation structures, risk of damage to electrical cables, risk to the structural integrity of the wind turbine by e.g. collision with a fishing vessel. Please note that the risks have been expressed as a risk to the OWE development, but that this also entails a risk for a fishing vessel.

The included fishery types were specified as vessels operating with engine sizes over 300 hp and using beam trawls, otter trawls or pelagic trawls.

Please note that OWE development is not seen here as a sea use that is categorically incompatible with fisheries. Other types of fishery may combine with wind turbines very well, e.g. with smaller vessels and static gears.

Additional information can be found in Van der Wal et al. (2011).

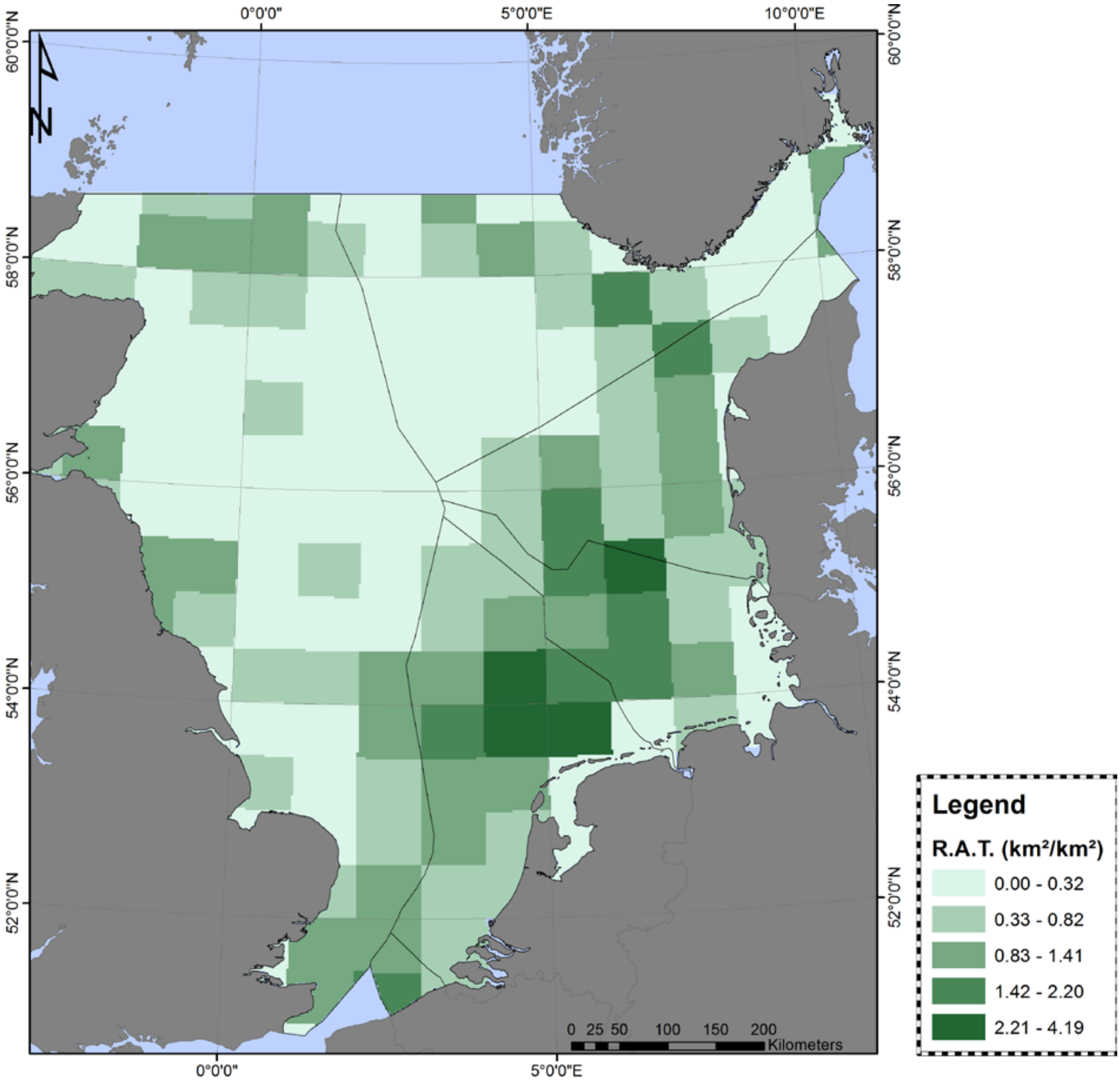

Figure 5 Fishery Effort, expressed as R.A.T or relative area trawled as included in the WINDSPEED dataset Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014). Spatial resolution equals ICES-blocks.

Table 4 Area (km²) experiencing a certain level of fishery effort (or pressure) by country.

Fishery Impact (R.A.T.) Range	BE	DE	DK	NL	NO	UK
0.00	0.0	481.3	18.8	700.0	987.5	218.8
0.01-0.10	0.0	5418.8	1675.0	4387.5	31412.5	38825.0
0.10-0.25	0.0	5293.8	9518.8	2231.3	18768.8	62631.3
0.25-0.50	75.0	0.0	4218.8	3243.8	16550.0	35331.3
0.50-0.75	406.3	7531.3	17456.3	16568.8	6618.8	17850.0
0.75-1.00	0.0	2375.0	7243.8	7300.0	3600.0	10887.5
1.00-1.25	1412.5	3625.0	6856.3	11056.3	3281.3	12550.0
1.25-1.50	0.0	3487.5	3506.3	1300.0	0.0	16162.5
1.50-2.00	1575.0	7162.5	5875.0	3800.0	1018.8	87.5
2.00-3.00	0.0	3337.5	987.5	6437.5	3318.8	0.0
3.00-4.00	0.0	2625.0	900.0	3650.0	0.0	0.0
4.00 +	0.0	0.0	0.0	3687.5	0.0	0.0

As previously mentioned, for the purpose of this study the fisheries that are included in the fisheries dataset are those that were originally included in the WINDSPEED dataset: these are the fisheries that deploy mobile/towed fishing gears such as beam trawls, shrimp trawls, otter trawls and pair trawls. The smaller vessels and static gears are not included. To determine a sensible area touched by a fishing vessel during a day of fishing (the unit used in the WINDSPEED datasets), an estimate was made on the yearly average of the area trawled on the Dutch Continental Shelf (DCS) for the period 2005-2011 for the gear types: beam trawl, otter trawl and pair trawl. This was based on assumptions regarding gear width and vessel speed while fishing for beam trawl vessels with engine sizes of 300 hp and above, which for the DCS-dataset constitutes over 90% of the effort (by time). These values have a.o. been documented in Slijkerman *et al.* (2013). From the combined data an estimated value for the area fished per fishing day of 1.7 km^2 is reached, see Table 5. Reversing the calculation using the assumed gear widths and speed while fishing, the net duration of a fishing day (days at sea) would be 6 hours. This seems acceptable as days as sea also include days travelling to the fishing grounds and back to port, thus lowering the time effectively spent fishing. Note that this estimated area trawled per fishing day is based on data from the Dutch part of the North Sea, which has been extrapolated to the whole study area by assuming that it represents an average value for the southern North Sea.

Table 5 Summary of data underlying the estimated area trawled per fishing day, based on data from Slijkerman et al. (2013).

Factor	Value	Remarks
Fishing days	48567.37 (d)	Representing all ICES rectangles intersecting the DCS
Area DCS	63563.9 (km^2)	-
Hours actively fishing	296498 (h)	Representing NCP-wide effort, beam trawl, otter trawl and pair trawl (annual average 2005-2011)
Fishing speed	11.71 (km/h)	Geometric mean of speed range, converted from knots
Gear width	12 (m)	*2 for each side of the fishing vessel
Estimated area trawled	83350 (km^2)	1.29 times area of DCS
Estimated area trawled per fishing day	1.7 (km^2)	Calculation based on the data above

3.2.1.3 Marine Protected Areas

As mentioned in the introduction of this case study, Marine Protected Areas could be included in the assessment, although it is not part of the project goal. The major source of information for this dataset has been the Natura2000-database as maintained by the European Environment Agency. For the WINDSPEED-project this has been added to by checking whether relevant national Marine Protected Areas or nature conservation areas existed.
Additional information can be found in Van der Wal et al. (2011).

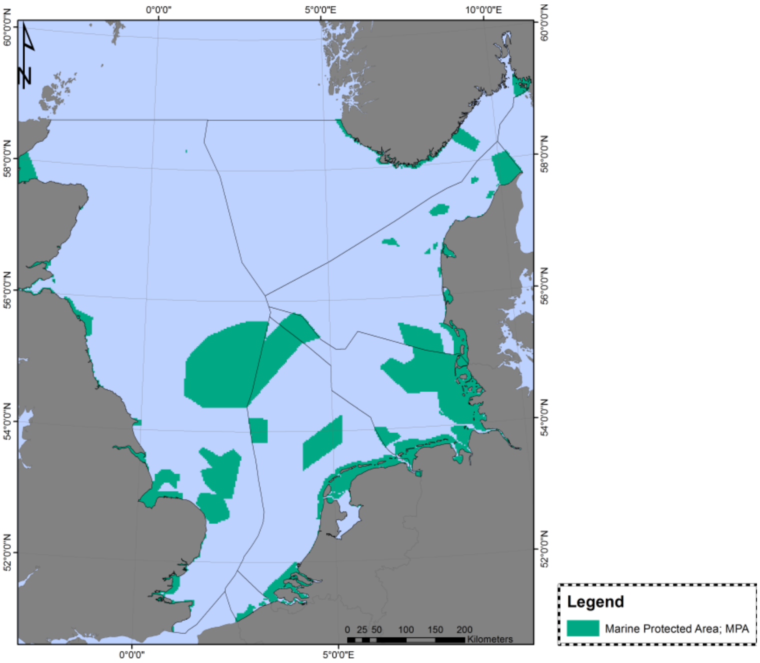

Figure 6 Marine Protected Areas across the study area. Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014).

Table 6 Area (km²) within and outside Marine Protected Areas by country.

	BE	DE	DK	NL	NO	UK
Protected area	443.8	18037.5	7325.0	14962.5	2718.8	28025.0
Remaining area	3025.0	23300.0	50931.3	49400.0	82837.5	166518.8
Total area	3468.8	41337.5	58256.3	64362.5	85556.3	194543.8

3.2.2 From pressure to ecosystem component

As mentioned previously, the five pressures caused by OWP and fisheries are all leading to habitat loss, i.e. area no longer suitable as habitat for the different ecosystem components. The endpoint for the CEA is therefore habitat loss. For OWP it is assumed that there is a 100% loss (impact severity = 1, see Table 7) within the affected area (OWP including a zone, based on an estimated disturbance distance, see Table 3). For fisheries the loss is assessed as a fraction, depending on the pressure-ecosystem component relationship (see Table 7). The affected area is determined by the fishery effort (see Table 4 and Table 5).

Table 7 Impact severity for both activities included in the case study: OWE and Fishery.

	OWE*	Fishery		
	Impact Severity	**Impact Severity**	**Source**	**Remarks on impact severity from fishery**
Benthos	1	0.6	Based on literature (ICES, 2012a)	Reduction in benthic biomass from Hiddink et al. (2006) as quoted in ICES (2012a)
Fish	1	0.3	Estimation	Fraction of species extracted by fisheries is about 0.3 presently (estimation by the authors of the underlying report), acceptable for many, but somewhat high for more vulnerable species
Birds	1	0.01	Estimation	No bycatch problems under consideration so set a 1% or 0.01 (below the 1.7% threshold as set for porpoise[2])
Marine mammals (harbour porpoise)	1	0.02	Estimation	Bycatch is considered a problem, also in the North Sea (exceeding 1.7%[2] of the population, so 2% or 0.02 is just over that threshold)
Marine mammals (seals)	1	0.01	Estimation	No bycatch problems under consideration so set a 1% or 0.01 (below the 1.7% threshold[2])

* It is assumed that the loss of habitat within the affected area is 100% for OWP (fraction = 1)

For Offshore Wind the differentiation between ecosystem components has been made in an earlier step by distinguishing different disturbances distances. Also it needs to be considered that once operational the effect of the OWE park on its surroundings is permanently present (year round).

For Fishery the distinction between ecosystem components is based on the following reasoning and references. Fisheries impact on benthos is based on ICES, 2012a where Hiddink *et al.* (2006) is quoted for a reduced benthic biomass of 56%. Here this has been interpreted as an impact severity of 0.6. Fisheries impact on fish is also based on information provided by ICES a.o. ICES 2012b, which advises that the fisheries induced mortality in 2012 could be safely increased from 0.20 to 0.25. However an earlier advice (ICES, 2012a) also contains an advice for a 15% decrease in TAC (total allowable catch). Sole and plaice are the main species considered in these sources. These are also some of the most important target species of the fleet segments that dominate the fishery effort included in our dataset. From this an impact severity of 0.3 is derived for Fishery on fish.
For harbour porpoise the impact severity is derived from assessments made by ICES (2013a) where the bycatch level for the population in the North Sea is judged as problematic because it exceeds 1.7%[2]. This value has been interpreted as 0.02 for impact severity of Fishery on harbour porpoise. The same reports also consider the impacts on other marine mammals such as seals as well as birds. For both groups the bycatch level is above zero but below that same 1.7% level. This is interpreted for the

[2] An IWC-ASCOBANS workshop (International Whaling Commission – Agreement on the Conservation of Small Cetaceans of the Baltic and North Seas) determined that a total anthropogenic removal beyond 1.7% of the best estimate of population abundance should be considered unlikely to meet the management objective of maintaining porpoise abundance at 80% of their carrying capacity

purposes of this case study as an impact severity of 0.01 for Fishery on both Birds as a group and both species of seal (grey seal and harbour seal).

In the section below the ecosystem components are discussed, including their data sources.

3.2.2.1 Benthos

As for the OWE and the fisheries data, spatial data on the benthos of the North-East Atlantic has been collated by the WINDSPEED-project. Figure 7 shows the benthos distribution (expressed as benthos value) in the North-East Atlantic. The benthic value is based on benthic community composition or benthic biodiversity. Additional information can be found in Van der Wal et al. (2011).

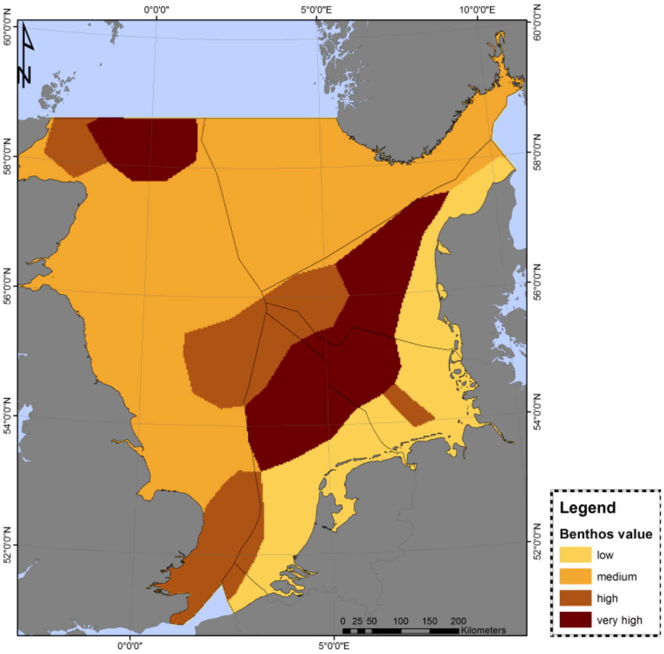

Figure 7 Benthic Value (classes) from the WINDSPEED-project. Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014).

3.2.2.2 Birds

The data on birds is based on the wind farm sensitivity index (WSI), developed by Garthe & Hüppop (2004). This methodology was used for the WINDSPEED project, where a birds WSI index for the Dutch North Sea was developed. The WINDSPEED birds WSI index builds on work by Garthe & Hüppop (2004) and combines a species-specific wind turbine sensitivity index (WTSI) with count data on the number of birds present in an area. The WTSI has been calculated for the 33 most numerous species in the Dutch sector of the North Sea, and takes nine factors into account:

A manoeuvrability in the air
B usual flight height of a species
C amount of time spent flying
D a measure relating to how active a species is during the night
E sensitivity to disturbance by ships
F a measure for a species flexibility regarding choice of habitat/area
G total biogeographical population size
H normal survival rate for adult birds
I status according to “European Threat and Conservation Status” (Tucker and Heath, 1994).

For each factor a score from 1 (very low) to 5 (very high) was given. The WTSI is calculated as follows (Garthe & Hüppop, 2004): = ((A3+B3+C3+D3)/4)*((E3+F3)/2)*((G3+H3+I3)/3)

For each grid cell data, the vulnerability was determined as:
$WSI = \sum_{species} (\ln (density_{species} + 1) \times WTSI_{species})$
Thus, for each species, the respective WTSI value was multiplied with the natural logarithm of its density (+1, to avoid undefined values) and subsequently summed over all species. The range of WSI scores was divided into three classes representing areas of less concern (the lowest scores); areas of concern (the median scores) and the areas of high concern (the highest scores), see Figure 8.

Additional information can be found in Van der Wal et al. (2011).

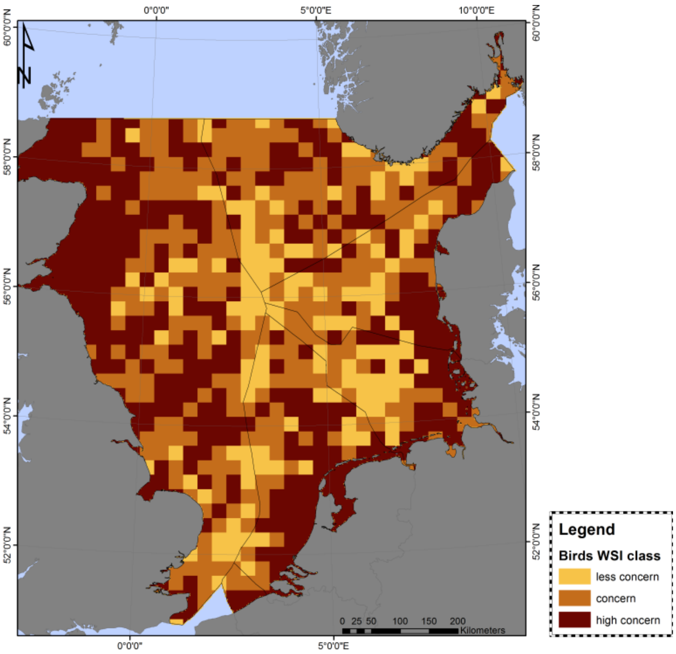

Figure 8 Birds WSI index (classes) from the WINDSPEED-project. Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014).

3.2.2.3 Fish

Fish are represented in the assessment by the distribution of fish species richness. Data from the WINDSPEED project is used, which is based on several years of surveying fish species with benthic gears as reported in Ter Hofstede et al.(2005) who focussed on 'natural value'-maps for fish.

Figure 9 is a map showing species richness, where the number shown has been standardised to account for different levels of sampling density across the North Sea. Additional information can be found in Van der Wal et al. (2011).

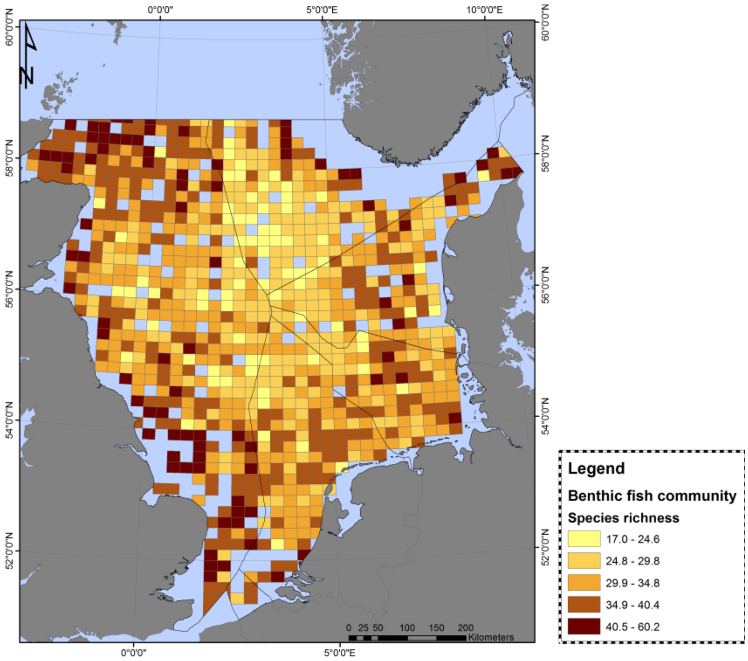

Figure 9 Fish Species Richness as used in the WINDSPEED-project. Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014)

3.2.2.4 Marine mammals

The WINDSPEED project collated data on marine mammals based on three species that are relatively common and are well-studied (to some extent) within the WINDSPEED area: Common seal (*Phoca vitulina*); the Grey seal (*Halichoerus grypus*); and the Harbour porpoise (*Phocoena phocoena*).

Through CEFAS and their paralleled case study, a set of GIS-data on the presence and abundance of several dolphin and whales species was made available. The original source of this data is Reid *et al.* (2003). More information on the implementation of marine mammals in this study has been included in Appendix A.

3.2.3 Weighting of ecosystem components

To ensure an equal weighting of each ecosystem component, all components should have the same aggregation level, i.e. either species groups or specific species. However, in this case study, three of the four ecosystem components are assessed on a group level, whereas marine mammals are assessed species specific, see Table 8. Therefore, for this case study, additional weighting is applied to account for the number of species that an ecosystem component represents.

Table 8 The maximum number of species a dataset may represent at a given location.

Ecosystem component	**No. of species**
Benthos	40
Fish	60
Birds	23
Marine mammals -Harbour porpoise	1
Marine mammals -Seals	2
Total	*126*

This choice was made as it was deemed that adding the five datasets and dividing the result by five to reach a final weighed result would overly favour the marine mammals (harbour porpoise and seals) at the expense of mainly the fish species. For fish species the number of species in the benthic fish community was available as a dataset. The dataset is geographically explicit and the maximum number of species in the dataset is 60. For the datasets on Birds (WSI) and Benthic value, no direct number for the maximum value was available in the dataset and a method has to be devised to transform the available classes to an estimated number of species. For Benthic Value an unpublished report from the MESH project, that analysed the benthic community of the Dutch Continental Shelf, was used and the maximum number of species was nearly forty. Based on this the following classification was applied for Benthic classes: low= 10; medium = 20; high = 30 and very high = 40 species. For Birds as considered in the WSI-dataset a similar approach was chosen. From the tables accompanying the dataset it becomes clear that a total of 26 species has been included. However as these species have very different characteristics with some clearly preferring inshore areas of the North Sea and others favouring the (far) offshore parts. The maximum number of species occurring at a given location was set at 90% of that theoretical maximum for the highest of the three classes then dropping 20% for each of the lower classes. Thus the classes from the Birds WSI classes are converted to species numbers as follows: less concern = 13; concern = 18; high concern = 23 species.

This combination of data and assumptions results in a relative biodiversity map as shown in Figure 10. The maximum fraction of species that is reached is 0.91 from a total of 126 species = 115 species.

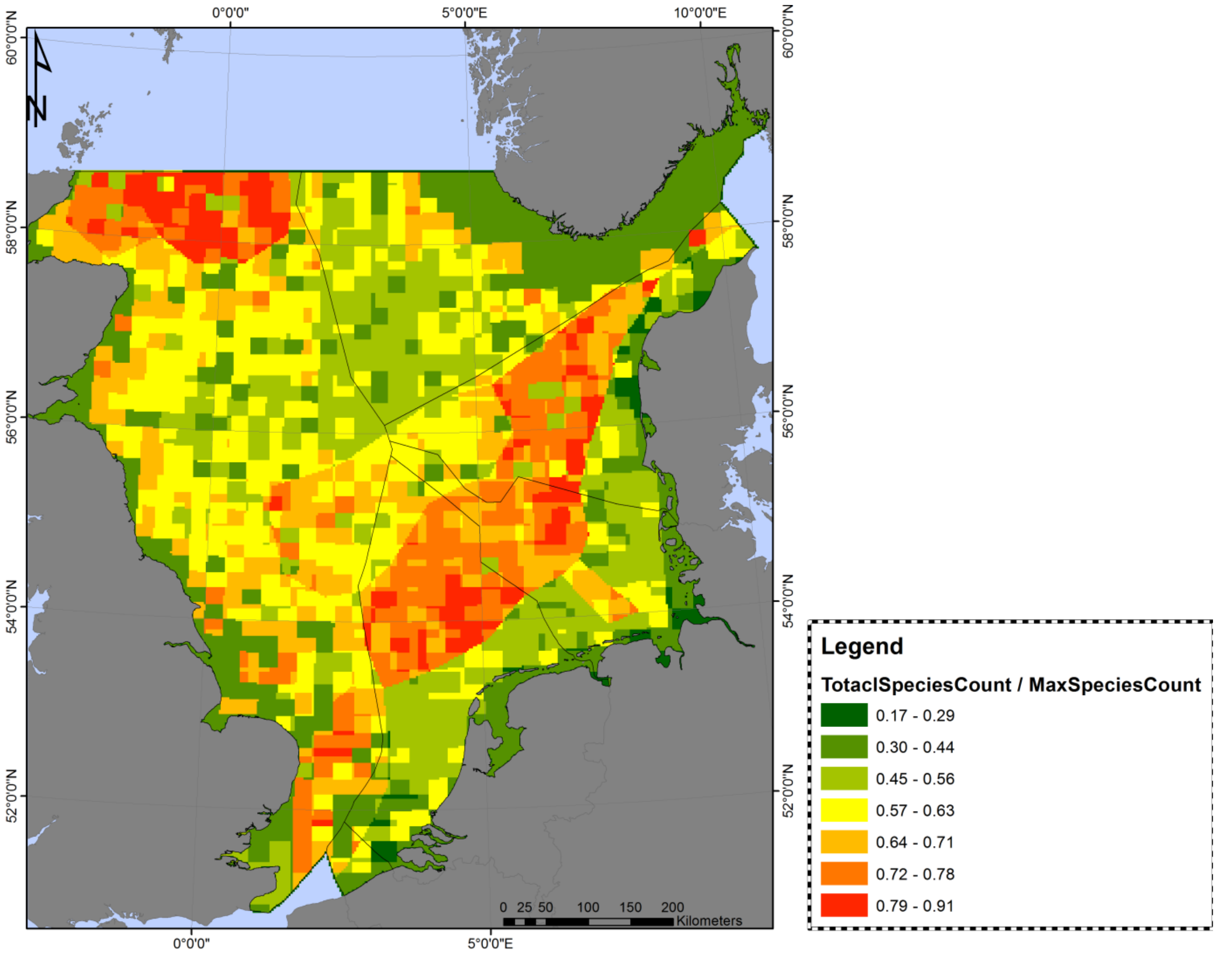

Figure 10 Relative biodiversity across the study area. Sources: Van der Wal et al. (2011) and Jongbloed et al. (2014).

3.2.4 Geographical resolution of the case study.

For the case study the original datasets as described above have been combined into one single dataset (polygons). The original datasets have different spatial resolutions ranging from ICES-blocks of approximately 30 x 30 nautical miles (55.6 x 55.6 km) to a resolution of 2.5 x 2.5 km. The dataset of OWE has the highest resolution. Because the aim of this case study is to assess the cumulative effects of OWE development the combined dataset has been set to this resolution, i.e. 2.5 x 2.5 km.

4 Results

4.1 Mapped relative impact

With the inputs and choices made as outlined in the previous chapter the following results have been generated: mapped impact on the ecosystem attributed to OWE development and mapped impact of fisheries on the ecosystem. Both are presented as maps showing their relative contribution to the total impact on the ecosystem (Figure 11 and Figure 12).

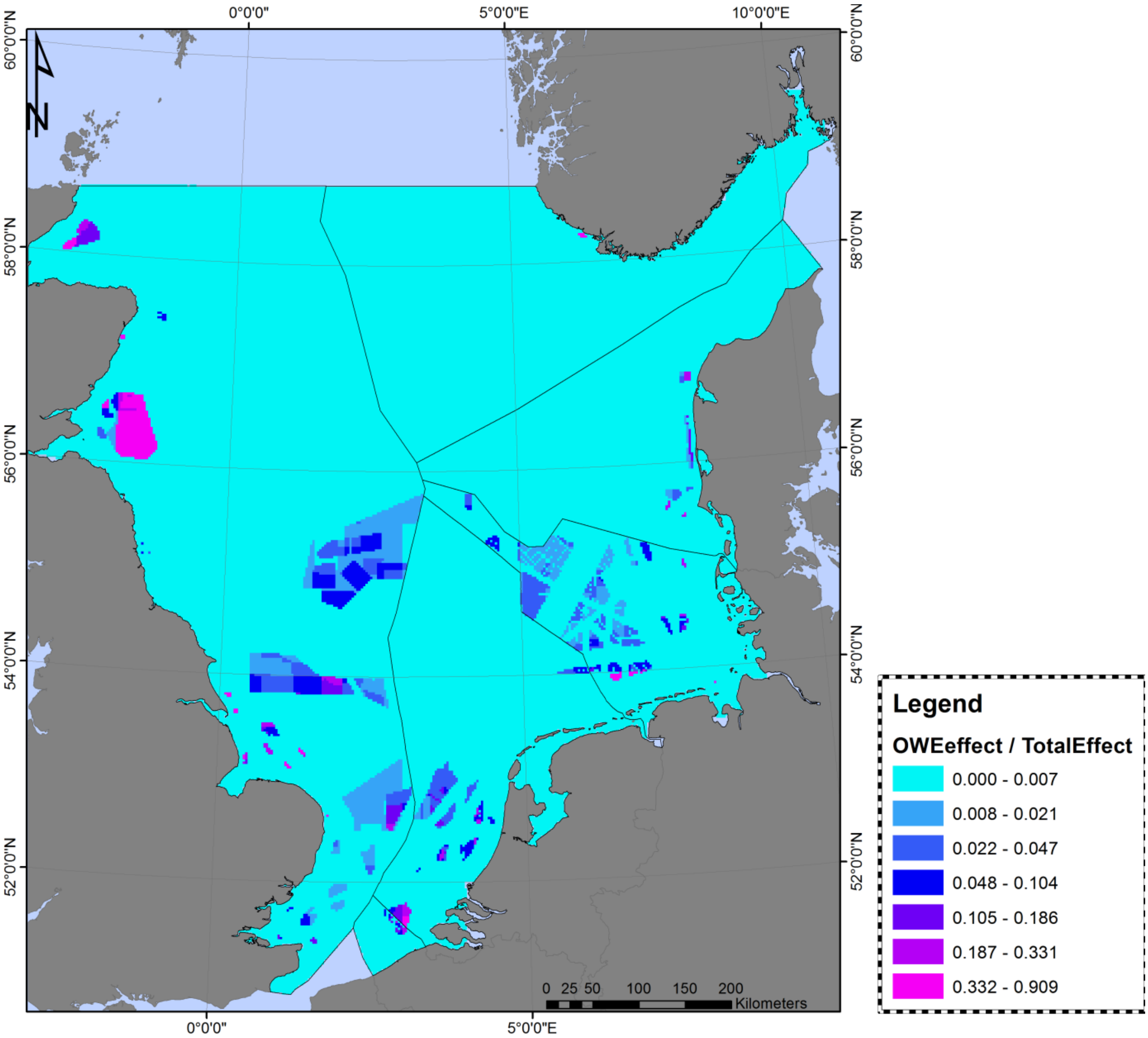

Figure 11 Contribution of Offshore Wind Energy to the Total Effect (of both OWE and Fisheries) on the Ecosystem as estimated in this case study.

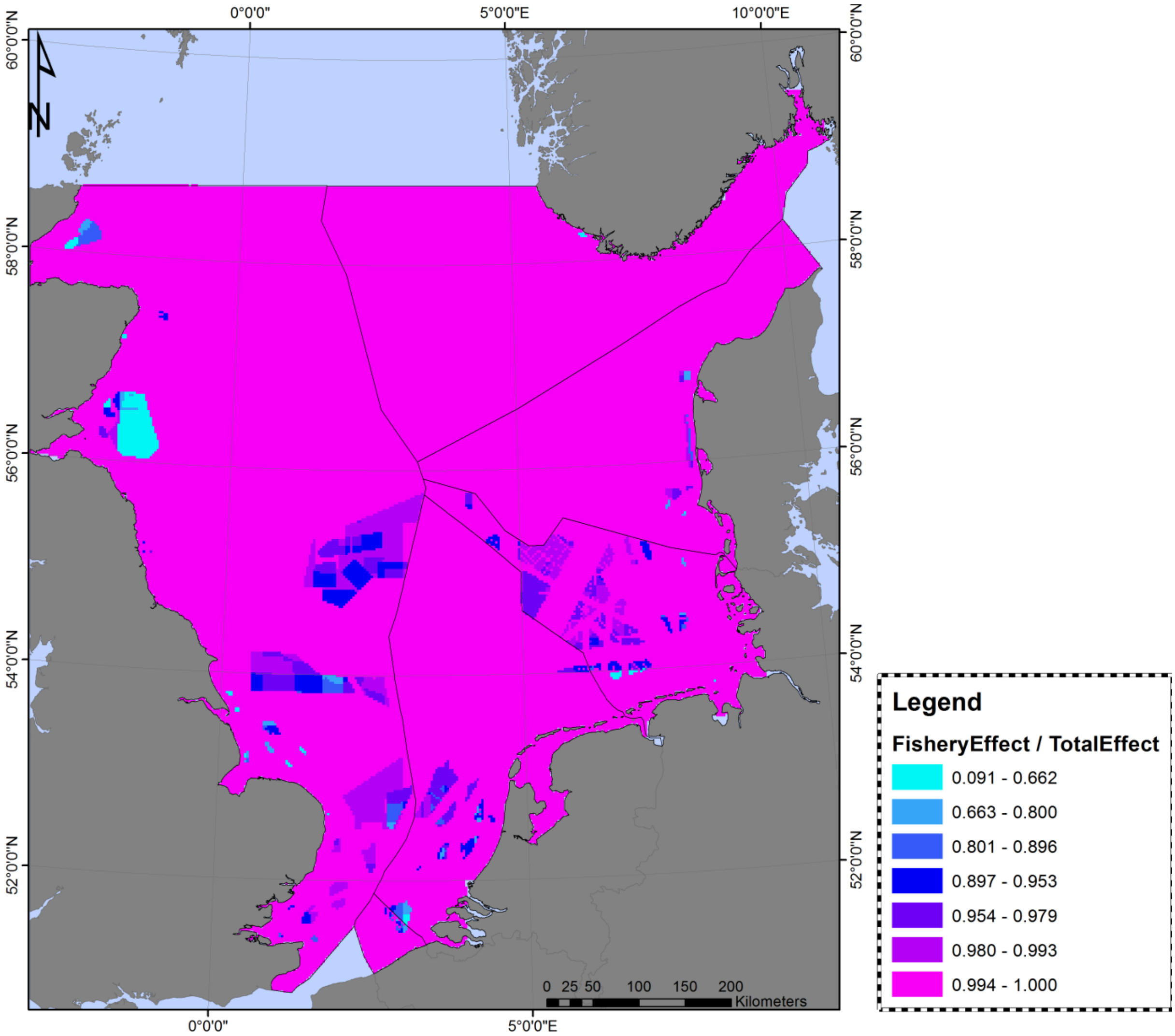

Figure 12 Contribution of Fisheries to the Total Effect (of both OWE and Fisheries) on the Ecosystem as estimated in this case study.

4.2 Affected area

The effect of OWE and fisheries is expressed as habitat loss, representing the loss of suitable habitat for benthos, birds, fish and marine mammals. The habitat loss caused by OWE is based on: underwater noise and vibrations (avoidance by fish and marine mammals), seafloor sealing through the underwater structures (benthos) and the presence of the structure above water (avoidance by birds to prevent collision). The habitat loss caused by fisheries is based on: extraction of species, both target species as by catch (fish, marine mammals and birds) and abrasion (benthos).

The resulting effects are shown in two tables that present the result by country, status of the OWE development and the timing of the development: Table 9 (OWE) and Table 10 (fishery). The affected areas are summarised for both sectors in Table 11.

Table 9 OWE impacted area (km^2) by Country, OWE status and timing of development.

	BE	DE	DK	NL	NO	UK
Operational						
2012 and earlier	0.6	0.1	1.6	1.0	0.0	2.9
2013-2020	0.4	0.5	0.0	0.0	0.0	3.3
Construction						
2013-2020	0.4	3.1	0.0	0.0	0.0	0.5
Authorised						
2013-2020	1.3	8.8	0.0	5.7	0.0	5.3
2020-2030	0.0	0.5	0.0	0.0	0.0	0.0
Application						
2013-2020	0.0	1.8	0.0	0.0	0.3	10.9
2020-2030	0.0	11.3	0.0	0.0	0.0	1.7
2030-2050	0.0	2.5	0.0	0.1	0.0	0.0
Proposed						
2013-2020	0.4	0.3	0.7	12.1	0.0	0.0
2020-2030	0.0	0.9	0.7	3.6	0.0	14.2
2030-2050	0.0	16.2	0.0	0.1	0.0	6.8
Development						
2013-2020	0.0	1.7	0.0	0.0	0.0	13.5
2020-2030	0.0	4.5	0.0	0.0	0.0	1.0
2030-2050	0.0	5.2	0.0	0.0	0.0	4.6
Total impacted area (km^2)	3.0	57.3	3.0	22.6	0.3	64.8
EEZ area (km^2)	3468.75	41337.5	58256.25	64362.5	85556.25	194543.75
Effect size (%)	0.09%	0.14%	0.01%	0.04%	0.00%	0.03%

Table 10 Fishery Impacted Area (km^2) by Country, OWE status and timing of development.

	BE	DE	DK	NL	NO	UK
Operational						
2012 and earlier	7.6	1.1	4.6	6.7	0.0	15.5
2013-2020	3.0	34.3	0.0	0.0	0.0	91.7
Construction						
2013-2020	1.0	49.4	0.0	0.0	0.0	0.3
Authorised						
2013-2020	12.0	298.0	0.0	63.6	0.0	99.3
2020-2030	0.0	29.0	0.0	0.0	0.0	0.0
Application						
2013-2020	0.0	74.0	0.0	0.0	0.1	210.7
2020-2030	0.0	663.0	0.0	0.0	0.0	10.1
2030-2050	0.0	68.4	0.0	3.4	0.0	0.0
Proposed						
2013-2020	9.2	2.5	33.3	131.3	0.0	0.6
2020-2030	0.0	60.1	23.6	140.8	0.0	1316.7
2030-2050	0.0	882.6	0.0	2.0	0.0	269.1
Development						
2013-2020	0.0	34.2	0.0	0.0	0.0	157.8
2020-2030	0.0	247.0	0.0	0.0	0.0	11.3
2030-2050	0.0	320.1	0.0	0.0	0.0	109.3
non OWP						
remaining	599.4	6803.6	9923.0	17108.9	4319.3	13926.0
Total impacted area (km^2)	632.2	9567.2	9984.6	17456.8	4319.4	16218.4
Inside OWP	32.9	2763.6	61.6	347.9	0.1	2292.4
EEZ area (km^2)	3468.75	41337.5	58256.25	64362.5	85556.25	194543.75
Effect size (%)	18%	23%	17%	27%	5%	8%

Table 11 Summary of impacted area by OWE and fisheries per country.

	BE	DE	DK	NL	NO	UK	Total
OWE Total (km^2)	3.0	57.3	3.0	22.6	0.3	64.8	151
Fishery Total (km^2)	632.2	9567.2	9984.6	17456.8	4319.4	16218.4	58179
EEZ area(km^2)	3468.75	41337.5	58256.25	64362.5	85556.25	194543.75	447525
Effect size OWE (%)	0.09%	0.14%	0.01%	0.04%	0.00%	0.03%	0.03%
Effect size Fishery (%)	18%	23%	17%	27%	5%	8%	13%

Table 9 shows the effect by OWE and fisheries as impacted area and as percentage impacted area of the total EEZ area for each country. The results indicate that effects are mainly caused by fisheries; OWE has a very small contribution.

In absolute numbers, the UK and Denmark have the largest area impacted by OWE, whereas the Netherlands and the UK have the largest area impacted by fisheries. Relative to the size of their EEZ, Denmark has the largest impacted area by OWE, followed by Belgium. For fisheries, the Netherlands has the largest relatively impacted area, followed by Denmark. Although Denmark has a relative high impacted area it also has the highest percentage of its EEZ designated as protected area, see Table 12. These numbers are visualised in Figure 13.

Table 12 MPAs per country.

	BE	DE	DK	NL	NO	UK
Protected area (km^2)	443.8	18037.5	7325.0	14962.5	2718.8	28025.0
Remaining area (km^2)	3025.0	23300.0	50931.3	49400.0	82837.5	166518.8
Total (km^2)	3468.8	41337.5	58256.3	64362.5	85556.3	194543.8
% protected	12.79%	43.63%	12.57%	23.25%	3.18%	14.41%

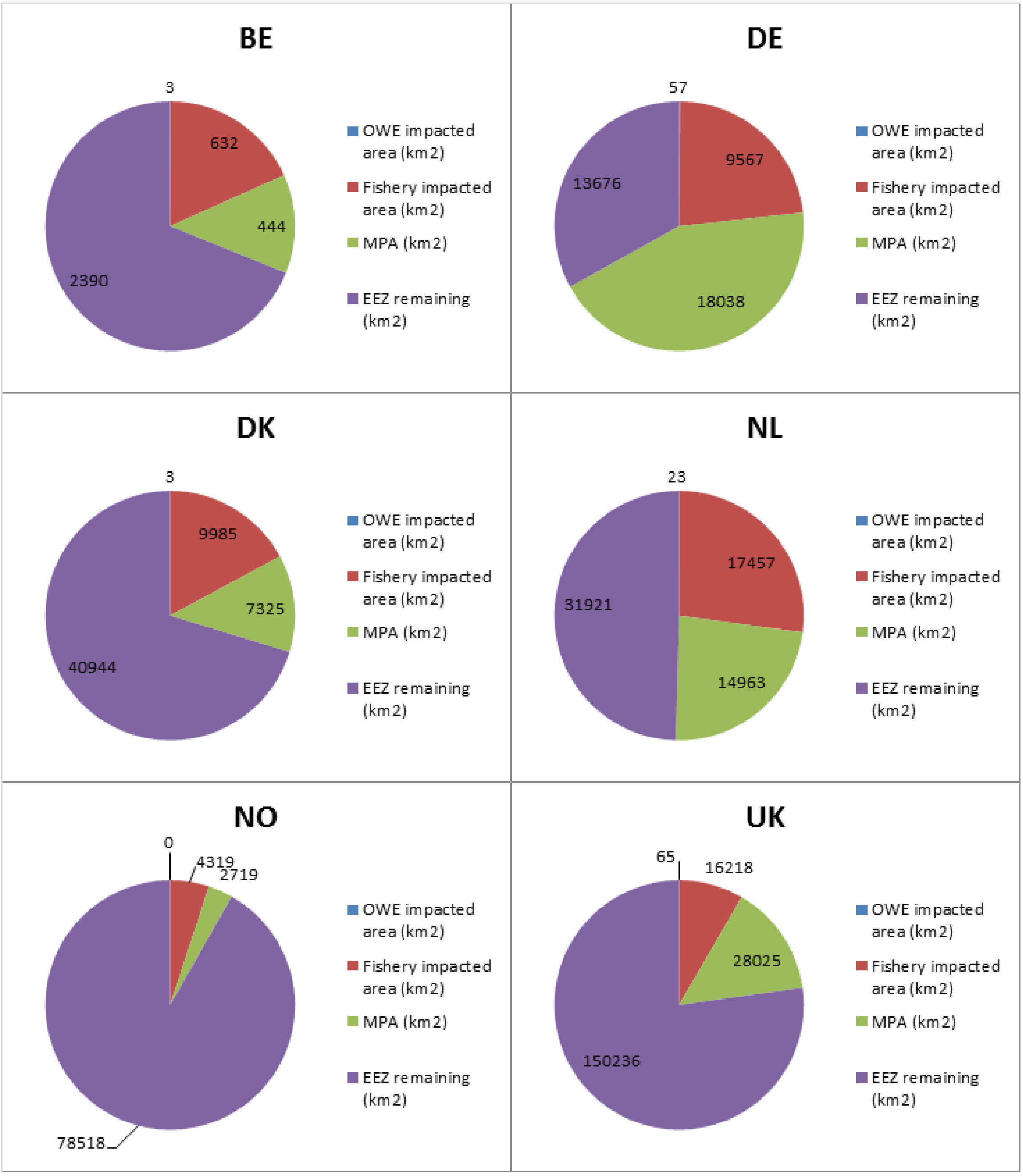

Figure 13 Total area of EEZ divided as impacted area (OWE and fishery), protected area (MPA) and remaining EEZ for each country.

Below (Table 13) results are presented that reflect the fishery effect in OWE and in MPA, based on the total area of concern (i.e. all countries). Please note that these are results for ca. 2050 (35+ years into the future) and should be treated with some reserve. In addition it is assumed that all eco-unfriendly fisheries will be excluded from all MPAs, an assumption that presently does not hold true as well. In most MPA fisheries are still allowed. The results indicate that fisheries within OWP and MPA contribute by 8.6% and 13.7% to the total affected area and fisheries, respectively. .

Table 13 Fishery effect in OWE and in MPA

	Area (km^2)	**Percentage**
Area of case study	447531.3	
OWE affected area	150.8	0.3%
Fishery affected area	58297.5	99.7%
Total affected area	58448.3	100.0%
Fishery Effect in OWE	5014.3	8.6%
Total affected area, excluding fishery effect in OWE	53434.1	91.4%
Fishery Effect in MPA	8011.1	13.7%

4.3 Cumulative effect of OWE

The habitat loss caused by offshore wind farm development in the southern North Sea according to the ambitions of the involved countries for the coming years is shown in Figure 14. The cumulative effect of current and future OWE development is presented in Figure 15. Assuming all developments will continue as planned, the cumulative effect (i.e. habitat loss) caused by OWP will be 77, 115 and 151 km^2 in the year 2020, 2030 and 2050, respectively.
Detailed geographical information on the current and planned activities of this sector can be found in the previous chapter (Figure 3).

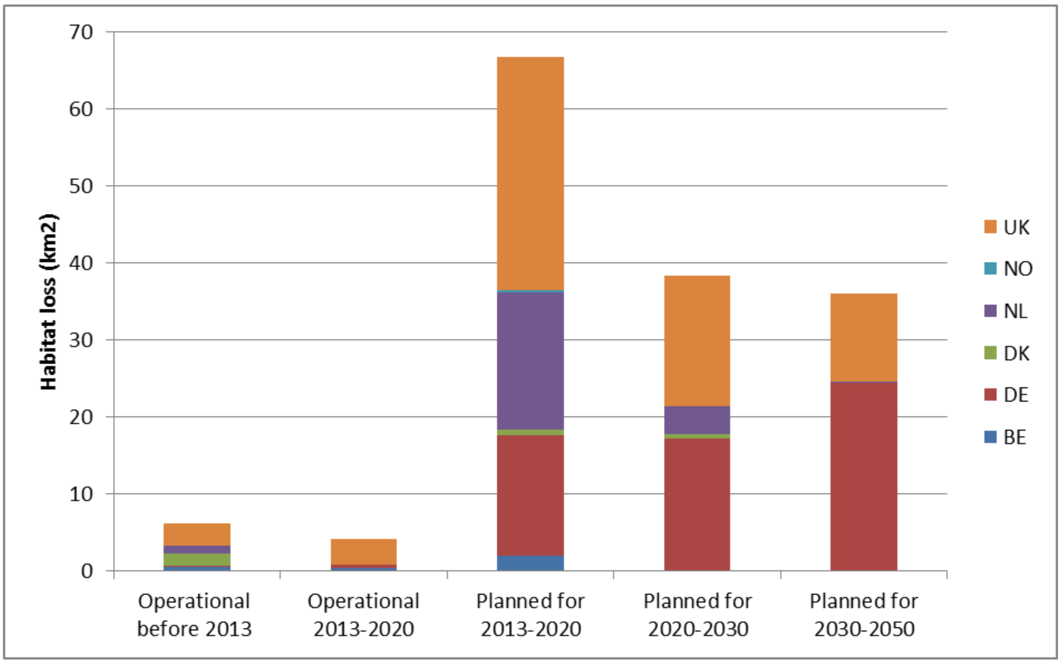

Figure 14 Assessed (potential) habitat loss caused by operational and planned OWP in the southern North Sea, presented per country, phase (operational versus planned) and time period.

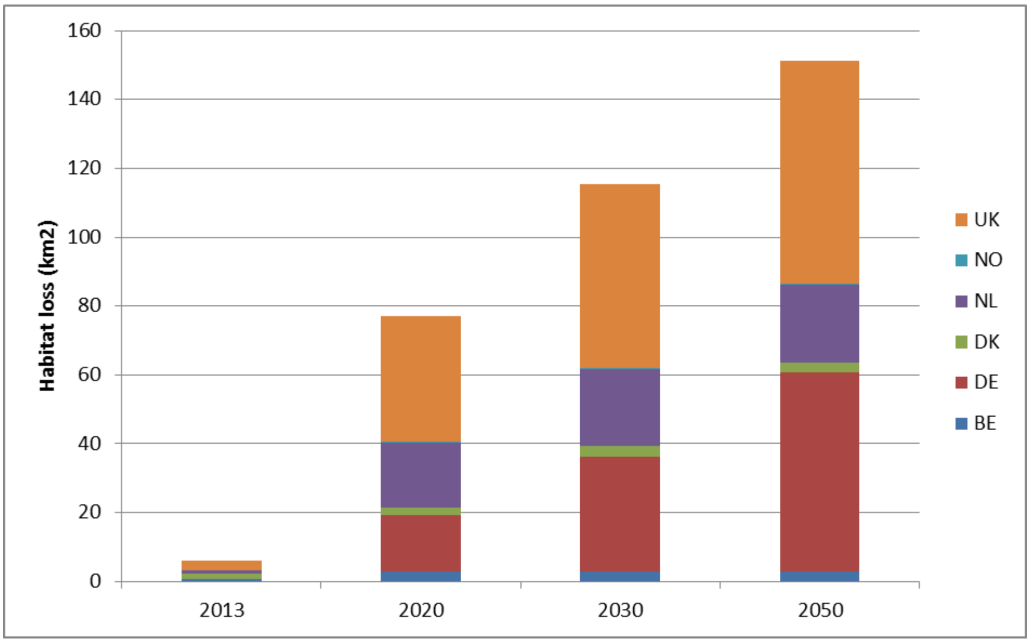

Figure 15 Assessed (potential) cumulative habitat loss caused by operational and planned OWP in the southern North Sea, presented per country and time period.

4.4 Shifting focus

Instead of showing the results for the complete study area and with a focus on activities (i.e. the two human activities OWE and fisheries), the database that is generated in the process of performing a CUMULEO-assessment also allows for the extraction of information focussing on the ecosystem components. This can also be done for a subarea of choice. For the purpose of this paragraph the estimated impacts on each of the four ecosystem components: benthos, fish, birds and mammals are presented for the adjoining Natura 2000 areas on the Doggerbank, where Germany, the Netherlands and the United Kingdom have designated marine protected areas. From this type of analysis an assessment can be made about the species or species groups that are impacted the most.

Table 14 Natura 2000 area Doggerbank and species involved.
Yes or No is given for species mentioned on the Standard Data Form as available from the EEA in the Natura 2000 Viewer (URL: http://natura2000.eea.europa.eu/), a minus is given for other species in NL and UK as no data is provided for this section. Please note that for Germany a further list of 42 other invertebrate species has been omitted from this table.

Designation Species	**DE**	**NL**	**UK**
Phocoena phocoena / Harbour porpoise	Yes	Yes	Yes
Phoca vitulina / Harbour seal	Yes	Yes	Yes
Halichoerus grypus / Grey seal	No	Yes	Yes
Other species			
Fulmarus glacialis / Northern fulmar	Yes	-	-
Larus fuscus / Less blackbacked gull	Yes	-	-
Morus bassanus / Gannet	Yes	-	-
Rissa tridactyla / Kittiwake	Yes	-	-
Uria aalge / Guillemot	Yes	-	-
Echiichthys vipera / Lesser weever	Yes	-	-

In Table 14 an overview is given of the species occurring in the Doggerbank area that are listed in either the Birds or Habitat Directive (EC 2009 and 2007) and that are included in the Standard Data Form

(SDF) for each of the three Natura 2000 areas. On the German SDF a number of other species – of importance in the area but not listed in either the Birds or Habitat directive- are also listed. Of these, the five bird species and the one fish species have been included, the 42 species of invertebrates have not.

On the next pages maps and tables will be presented showing the impact per ecosystem component (Benthos, Fish, Birds, Mammals) for the Doggerbank area. For comparability with the previously presented results tables, summarised results of the OWE Effect as well the Fishery Effect are also given.

Benthos Impact

The geographical distribution of the impact on the group of benthos species is shown in Figure 16, where the values range from 0.24 to 0.54 with a mean of 0.38 for the relative impacted area (km^2/km^2). The data shown in this map area summarised split by country, OWE status and timing of development in Table 15. Please note that in Denmark and the Netherlands no OWE development is expected for this area, which is why the table shows mostly dashes (no data) for these countries. For Germany there is just one OWE development/2030-2050, whereas in the United Kingdom considerable development is expected. This is expected to start already between 2013 and 2020 and then to continue.

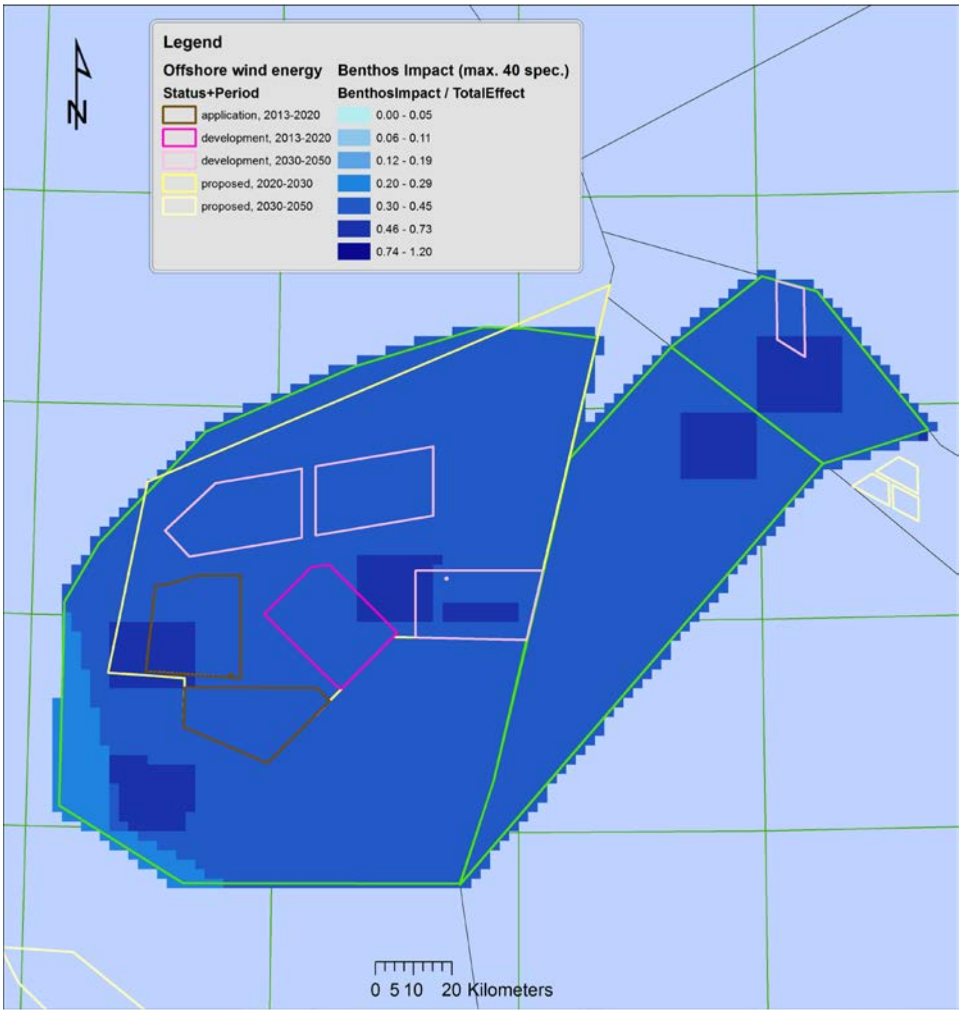

Figure 16 Benthos Impact (for all benthos species, max. 40) (as fraction of Total Effect) as estimated in this case study, here limited to the Doggerbank area.

Table 15 Benthos Impact (for all benthos species, max. 40) (as km² habitat loss) in the Doggerbank area, by Country, OWE status and timing of development.

	DE	DK	NL	UK	Total	Total as %
Application						
2013-2020	-	-	-	29.4	29.4	0.13%
Proposed						
2020-2030	-	-	-	124.1	124.1	0.55%
Development						
2013-2020	-	-	-	10.8	10.8	0.05%
2030-2050	6.8	-	-	42.6	49.4	0.22%
Outside OWP	67.0	4.8	216.9	213.0	501.6	2.24%
Total Benthos	73.8	4.8	216.9	419.8	715.3	3.19%
Area (km²)	1800	100	5025	15512.5	22437.5	

Fish Impact

The geographical distribution of the impact on the group of fish species is shown in Figure 17, where the values range from 0.08 to 0.48 with a mean of 0.34 for the relative impacted area (km^2/km^2). The data shown in this map area summarised split by country, OWE status and timing of development in Table 16. Please note that the same remarks hold for this table as for Table 15.

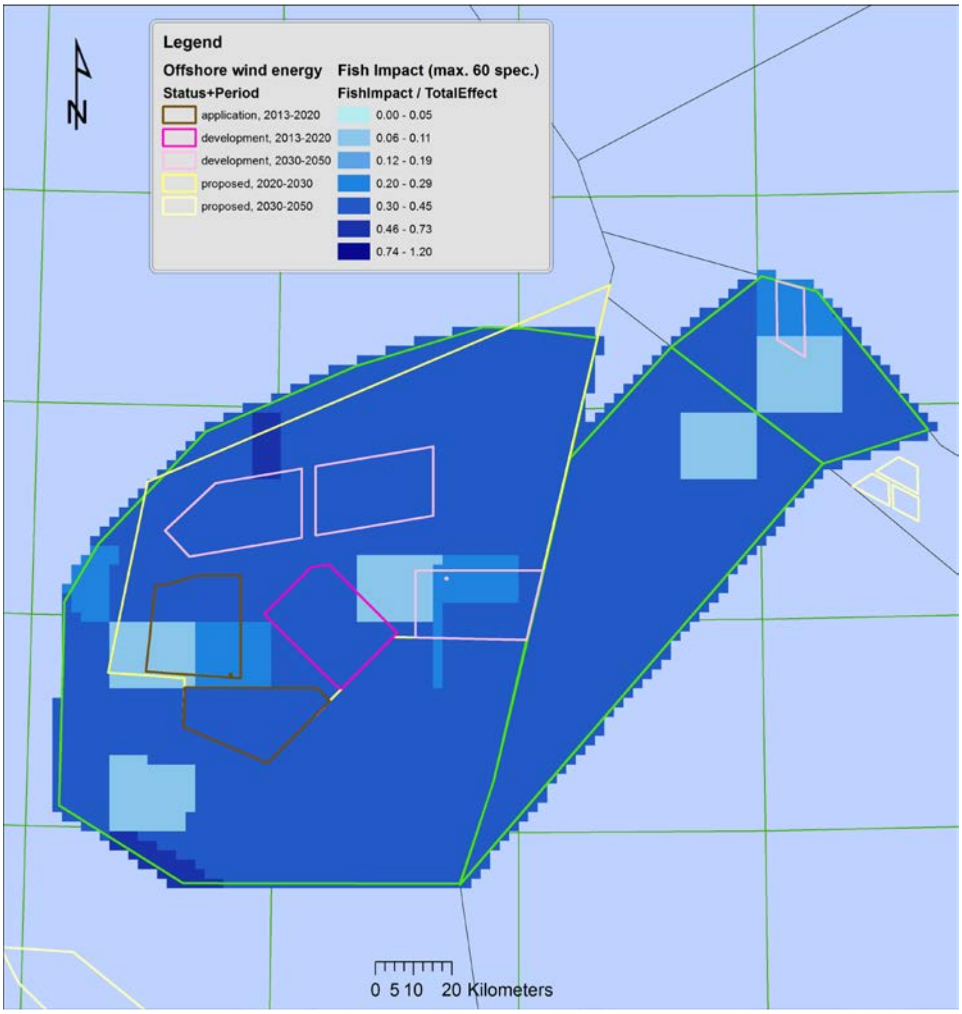

Figure 17 Fish Impact (for all fish species, max. 60) (as fraction of Total Effect) as estimated in this case study, here limited to the Doggerbank area.

Table 16 Fish Impact (for all fish species, max. 60) (as km² habitat loss) in the Doggerbank area, by Country, OWE status and timing of development.

	DE	DK	NL	UK	Total	Total as %
Application						
2013-2020	0.0	0.0	0.0	23.8	23.8	0.11%
Proposed						
2020-2030	0.0	0.0	0.0	121.9	121.9	0.54%
Development						
2013-2020	0.0	0.0	0.0	11.2	11.2	0.05%
2030-2050	3.3	0.0	0.0	41.2	44.5	0.20%
Outside OWP	43.1	4.0	194.4	214.2	455.7	2.03%
Total	46.4	4.0	194.4	412.3	657.1	2.93%
Area (km^2)	1800	100	5025	15512.5	22437.5	

Bird Impact

The geographical distribution of the impact on the group of fish species is shown in Figure 18, where the values range from 0.16 to 0.45 with a mean of 0.24 for the relative impacted area (km^2/km^2). The data shown in this map area summarised split by country, OWE status and timing of development in Table 17. Please note that the same remarks hold for this table as for Table 15.

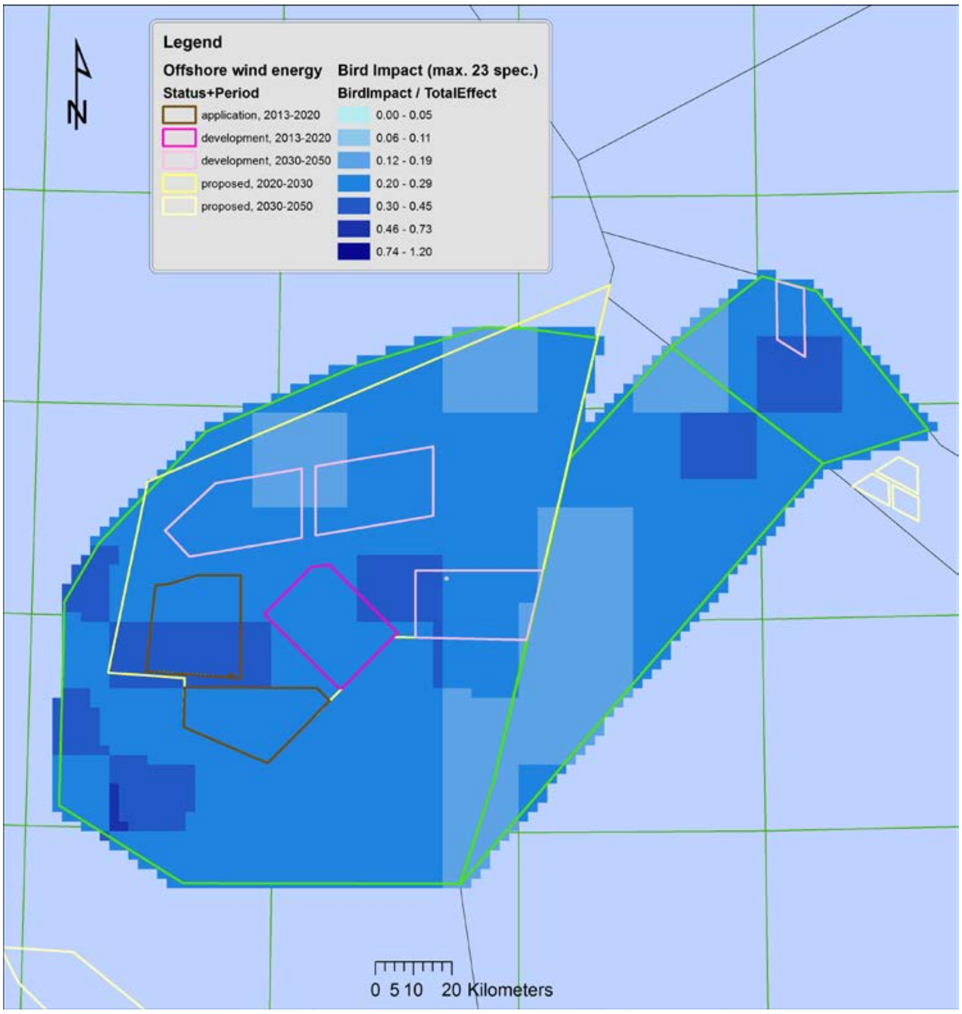

Figure 18 Bird Impact (for all bird species, max. 23) (as fraction of Total Effect) as estimated in this case study, here limited to the Doggerbank area.

Table 17 Bird Impact (for all bird species, max. 23) (as km² habitat loss) in the Doggerbank area, by Country, OWE status and timing of development.

	DE	DK	NL	UK	Total	Total as %
Application						
2013-2020	-	-	-	20.8	20.8	0.09%
Proposed						
2020-2030	-	-	-	78.5	78.5	0.35%
Development						
2013-2020	-	-	-	8.2	8.2	0.04%
2030-2050	4.1	-	-	26.1	30.2	0.13%
Outside OWP	39.5	2.9	119.0	143.0	304.3	1.36%
Total	43.6	2.9	119.0	276.6	442.1	1.97%
Area (km^2)	1800	100	5025	15512.5	22437.5	

Mammal Impact

The geographical distribution of the impact on the group of fish species is shown in Figure 19, where the values range from 0.03 to 0.06 with a mean of 0.04 for the relative impacted area (km^2/km^2). The data shown in this map area summarised split by country, OWE status and timing of development in Table 18. Please note that the same remarks hold for this table as for Table 15.

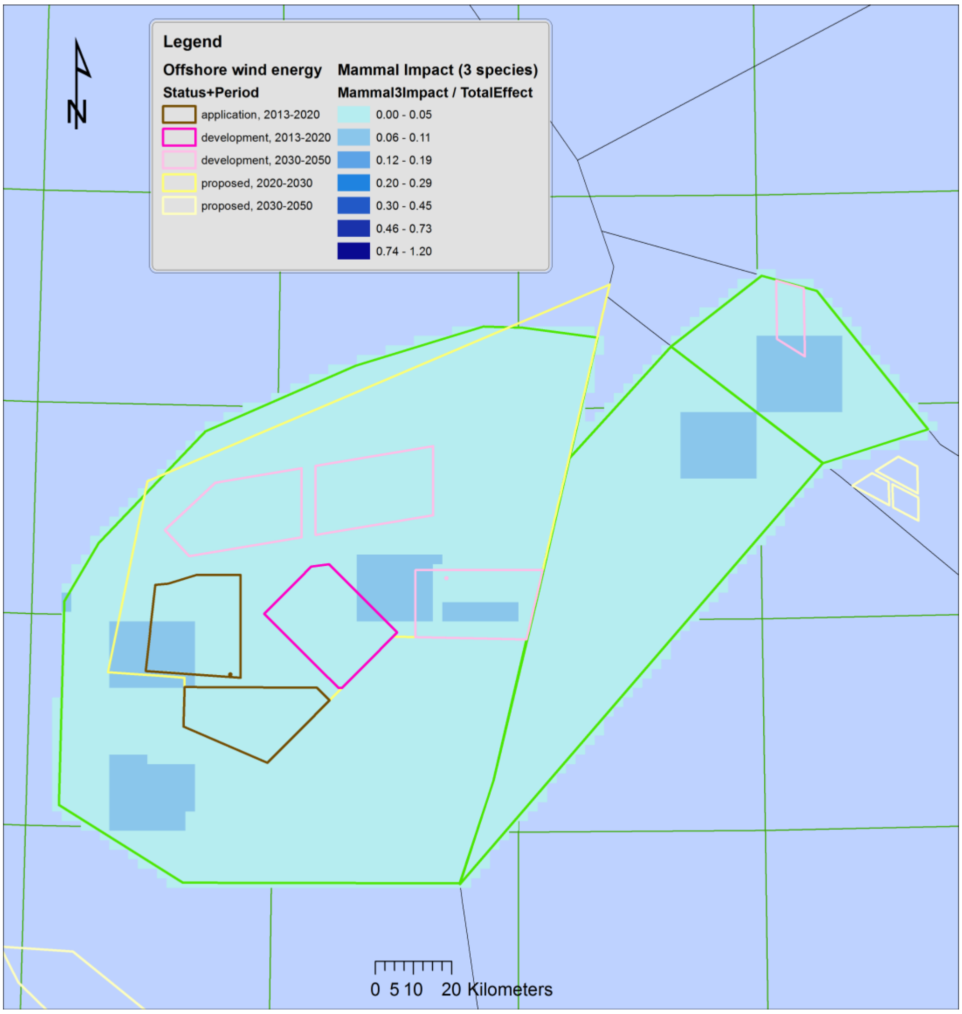

Figure 19 Mammal Impact (all three sea mammals) (as fraction of Total Effect) as estimated in this case study, here limited to the Doggerbank area.

Table 18 Mammal Impact (all three sea mammals) (as km² habitat loss) in the Doggerbank area, by Country, OWE status and timing of development.

	DE	DK	NL	UK	Total	Total as %
Application						
2013-2020	0.0	0.0	0.0	2.9	2.9	0.01%
Proposed						
2020-2030	0.0	0.0	0.0	12.4	12.4	0.06%
Development						
2013-2020	0.0	0.0	0.0	1.1	1.1	0.00%
2030-2050	0.7	0.0	0.0	4.3	4.9	0.02%
Outside OWP	6.7	0.5	21.6	21.9	50.7	0.23%
Total	7.4	0.5	21.6	42.6	72.1	0.32%
Area (km^2)	1800	100	5025	15512.5	22437.5	

Figure 20 shows the contribution of each of the four ecosystem components across the Doggerbank area to the total impact.

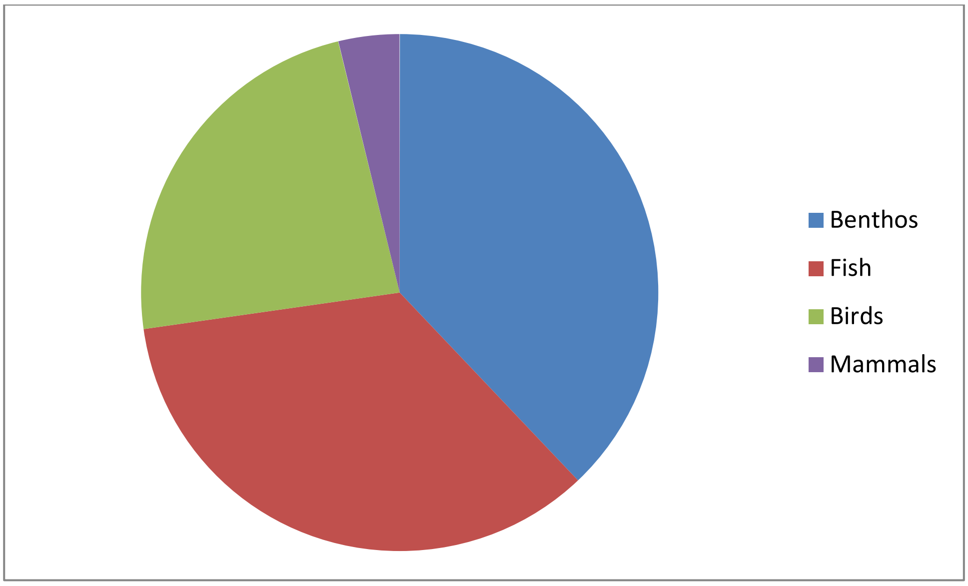

Figure 20 Share of each ecosystem component (group) in the total impact across the Doggerbank area, as estimated in this case study.

The following tables (Table 18 and Table 19) give a breakdown of the impacted area (km^2) for the Doggerbank area for both Offshore Wind Energy development as well as Fisheries, broken down by Country, OWE status and timing of development. These tables are basically the same as Table 9 and Table 10 presented earlier, with the difference that the earlier tables give the results for the complete study area instead of just the Doggerbank area.
Based on the information contained in these tables the relative contribution of each of the two human activities to the total effect on the Doggerbank area is < 1% for OWE development and > 99% for fisheries by 2050 provided all OWE development has become operational as assumed here.

Table 19 OWE impacted area (km^2) by Country, OWE status and timing of development, for the Doggerbank area.

	DE	DK	NL	UK	Total
Application					
2013-2020	-	-	-	3.7	3.7
Proposed					
2020-2030	-	-	-	3.9	3.9
Development					
2013-2020	-	-	-	1.8	1.8
2030-2050	0.6	-	-	4.6	5.3
Outside OWP	0.0	-	-	0.0	0.0
Total	0.6	0.0	0.0	14.0	14.6
Area (km^2)	1800	100	5025	15512.5	22437.5

Table 20 Fishery impacted area (km2) by Country, OWE status and timing of development, for the Doggerbank area.

	DE	DK	NL	UK	Total
Application					
2013-2020	-	-	-	73.3	73.3
Proposed					
2020-2030	-	-	-	332.9	332.9
Development					
2013-2020	-	-	-	29.6	29.6
2030-2050	14.0	-	-	109.3	123.3
Outside OWP	156.1	12.1	551.9	591.2	1311.3
Total	170.1	12.1	551.9	1136.3	1870.5
Area (km^2)	1800	100	5025	15512.5	22437.5

5 Discussion

5.1 Scope

5.1.1 Activities

5.1.1.1 <u>OWE</u>

The construction phase of an OWE park has been disregarded in this case study, mainly because presently there is no technical capability in the market (no suitable vessels) to allow for simultaneous construction of several OWE parks. However as there is a push to develop considerably more OWE capacity between now and 2020, in a.o. the United Kingdom, Germany and the Netherlands. And also considering newly developed plans to develop more OWE in the Danish sector of the North Sea, it seems reasonable to expect that this technical capability will increase.
A disturbance range of 20 km, relative to boundary of the OWP, has been used in Figure 21 to give a visual interpretation of locations where construction activities, most notably pile-driving (of mono-piles) may interact with each other. The contours have only been drawn for OWE under construction or authorised for development during the period 2013-2020. Please note that the chosen 20 km range can still be too optimistic, considering the indication by Wahl et al. (2013) that the behavioural response of harbour porpoises to pile driving may extend to distances greater than 20 km.

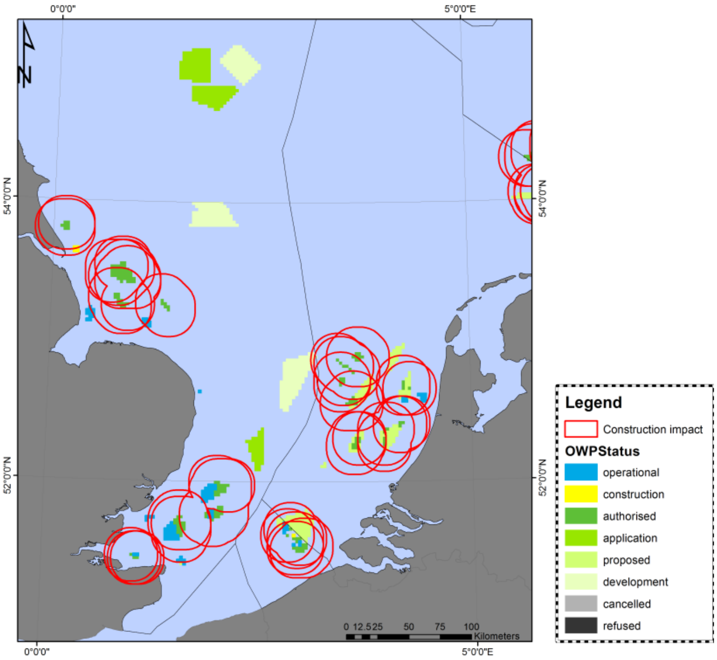

Figure 21 Visualisation of a 20 km impact range of OWE construction (pile-driving) on species such as Harbour porpoise.

With the evaluation of OWE development there exists a complicating factor arising from the very different impact of a wind farm during the construction phase and once operational. However there is a mitigating process at work as well. The area that is influenced during the construction phase is centred around the single foundation being installed and as a result the impacted area is also limited to essentially a single wind turbine being not the full extent of the wind farm, with often 60 or more wind turbines. This offset in impacted area is used to our advantage by considering the outer boundary of the OWE park as a reasonable first estimate of the impact area during construction.

This assessment is also dependent on technology choices that are known or partly known for operational OWE parks, those that are under construction or are nearing that phase, but for many that are planned for the more distant future technological progress may lead to improved performance and less environmental impact than is presently foreseeable. Some of the processes that may lead to different technology choices may also coincide with future OWE development moving into deeper waters where monopiles may no longer be the best available technology (also from an engineering point of view) and gravity-based or jacket-type foundations may become more prevalent. As a result of this, the expected impact on the natural environment during construction can decrease.
In contrast the impacted area during construction may also increase due to the development of a higher capacity to construct OWE, with more vessels and other equipment becoming available to complete the job. Presently the construction phase is a serial process where work is done mostly at one single point of construction. However in the future OWE construction may develop to a stage where two or more construction sites are active in parallel.

5.1.1.2 Fisheries

Considering fisheries it should be noted that over the last decade the pressure exerted by this sector has decreased. This is mainly due to fishing vessel being taken out of service – as commercial fishing vessels – and due to cutbacks in TAC (total allowable catch). Another force acting to reduce the ecological impact of fisheries is the increased use of innovative gear types. Gear types that are both more fuel efficient and therefore economical, but as much of those benefits coincide with less gear weight and improved selectivity which reduces the ecological impact. On the other hand ICES advice is predominantly to decrease TAC even further (in 2013 it was proposed to decrease the TAC by 15% (ICES, 2013a)). Even though for some species like sole and plaice an increase in F (fisheries induced mortality) is seen as acceptable, i.e. within safe boundaries for maintaining the fish stocks at sustainable levels.

5.1.2 Pressures

Only the pressures that were identified to be caused by the activities of concern (i.e. OWP and fisheries) were selected for this case study. Therefore, the pressures that are included in this case study does not provide an indication of the overall pressure on the study area (i.e. by all anthropogenic activities). For a more complete assessment e.g. adding offshore oil and gas platforms, pipelines and shipping the addition of further pressures is sensible and would include e.g. pollution.
The pressures and their impact, here expressed as habitat loss, yield useful insight into the relative importance of the selected activities, their development according to future scenarios and the related policy options that present themselves.

5.1.3 Ecosystem components

The ecosystem components assessed for this case study are (groups of) species, expressed as:

- Species richness for fish;
- Benthic value (based on benthic community composition or benthic biodiversity) for benthos;
- WSI index for birds (based on species-specific wind turbine sensitivity combined with the number of birds present in an area);
- Distribution and density for the marine mammal species harbour porpoise, grey seal and harbour seal.

Ideally, all ecosystem components would have the same aggregation level, i.e. either species groups or specific species. However, in this case study, three of the four ecosystem components are assessed on a group level, whereas marine mammals are assessed species specific. The choice for selecting specific marine mammal species was based on the very limited occurrence of other species (leaving only the three selected species) and the different distribution and sensitivity of the three common species. The use of both species groups as well as specific species in the assessment leads to unbalanced results. Therefore, for this case study, additional weighting is applied to account for the number of species that an ecosystem component represents.

5.1.4 Geographical resolution of the case study

For the case study original datasets have been combined into one single dataset (polygons) with a spatial resolution of 2.5 x 2.5 km. This spatial resolution is considerably higher than some of the original input datasets, such as fishery effort, and Birds WSI. However it was needed to go to this level of detail to represent the details of OWP-dataset with an acceptable degree of realism. Other grid sizes that were considered but rejected where 25 x 25 km (original resolution of the Birds WSI dataset) and 5 x 5 km. Almost all maps presented in this report have been produced using this gridded dataset, the level of detail it provides is such that the coarseness of the data is only noticeable at closer inspection.

5.1.5 Acceptance of methodology

The CUMULEO-approach has build a track record since its earliest inception for projects conducted for the WE@Sea research program starting in 2004 (a.o. Blankendaal *et al.*,2012). It has since then continually been improved to incorporate freshly acquired insights and adjusted to meet the requirements set by new projects, such as changing geographical scopes and focal points on both human activities and/or ecosystem components (o.a. de Vries et al., 2011).
A formal check on the acceptability to stakeholders of the methodology, including assumptions and default values has been part of the WindSpeed project. In a first round of five national stakeholder workshops the intended approach for realising the WindSpeed DSS was outlined to stakeholders and discussed. The stakeholders present at these workshops seemed satisfied and no major changes to the methodology were made. The result of this first consultation round has been documented in Soerensen (2009).
In a second round of workshops the DSS and some further project results were presented, resulting in a.o. the conclusion that the DSS was a useful tool in the Marine Spatial Planning process (Soerensen, 2011).

5.2 Policy on OWE and fisheries interaction

As explained before, for the present study a choice was made to limit the assessment to a balanced assessment of habitat loss as a result of the present and future development of offshore wind energy in the North Sea and how this interacts with fisheries. Beyond the direct impact a considerable space is available for policy measures changing the outcome of the assessment of this (limited) CEA. The extent to which OWE development interacts with fisheries is very much dependent on policy choices regarding whether fisheries are or are not allowed to operate inside offshore wind farms. Also options to fish within wind farms may be limited to specific subsets of fisheries. National policies are presently quite different between countries in this respect. In countries like Denmark and the United Kingdom the general approach appears to be to allow fishermen to operate inside wind farms. However the fisheries fleets of these countries are dominated by smaller vessels. They also deploy gears that are most likely safe to operate between wind turbines, safe in this respect signifying a low risk of causing damage to the wind turbines, cables or other infrastructure of the wind farm. The present policy in Belgium, the Netherlands and Germany is to ban fisheries from OWE areas. A considerable portion of the fishery fleets of these countries consists of large and powerful vessels operating gear types that are much more likely to cause damage to the infrastructure of the wind farm.
With the latter policy in place OWE areas can be seen as de-facto MPAs, and from this point of view it makes sense to include MPAs in the mix as well. With policies in place that turn OWPs into MPAs it makes sense to how much combined protected area is achieved when this combination is considered.

When considering both the area that is expected to be developed for OWE generation over the next year, as reflected in the OWE dataset that was prepared for this case study it would seem that a viable policy option could be to upkeep the present policy of BE, NL en DE not to allow fisheries to operate inside wind parks. Please note that this suggestion is limited to vessels operating mobile (towed) gears such as beam trawls, pair trawls and otter trawls, as well as large pelagic trawlers. For small vessels operating e.g. static gears, such as dominating the UK and DK fishing fleets, wind parks could still be accessible.

It would make sense to decrease the TAC with the amount that was formerly fished inside OWE area. As this development will slowly increase over the coming years. Even when combined with the area that is protected inside marine protected areas the total impact on fisheries may only be to improve the profitability of the sector. Main results underpinning the suggestion to exclude (incompatible) fisheries from OWE area are presented in Table 13. As such it would seem a safe way to proceed with OWE development to exclude fisheries and support that with a matching decrease of the TAC for the first few years at least. Once it becomes clear that either the fisheries sector are suffering too much from this gradual increase in adverse pressure or the ecology of the North Sea is clearly rebounding, the policy can be adapted to that new situation.

5.3 General conclusions based on results

Based on the results of this case study, it can be concluded that the cumulative effects of offshore wind farm development in the southern North Sea, according to the ambitions of the involved countries, cause a habitat loss of 77, 115 and 151 km^2 in the year 2020, 2030 and 2050, respectively.

The cumulative (combined) ecological effects of fisheries is considerably larger than that of OWE development. Even when considering the fact that most of the OWE development included in that assessment will be realised over the upcoming years even decades. The cumulative affected area by fisheries is 13% of the study area whereas the cumulative affected area by OWE is only 0.03%.

6 Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 124296-2012-AQ-NLD-RvA). This certificate is valid until 15 December 2015. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Fish Division has NEN-EN-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 1th of April 2017 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

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Justification

Rapport C078/13, Comparing methods to approach cumulative effects in the North-East Atlantic: CUMULEO case study

Project Number: 4305205701

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

Approved: Ruud Jongbloed

Signature:

Date: April 2014

Approved: Floris Groenendijk
Head Department Maritime

Signature:

Date: April 2014

Appendix A. Selection of marine mammal species

An important data source for this case study is the WINDSPEED dataset, as described in Van der Wal et al. (2011) and Jongbloed et al. (2014). In addition to the ecosystem components already included in the WINDSPEED dataset a series of GIS-datasets on cetacean abundance in the North-Western Atlantic originating from Reid et al. (2003) which was made available via CEFAS has been evaluated for use in this study. Other richer data sources have already been identified e.g. ICES Datras Fish distribution data but have not been made operational as they would exceed the available constraint on a.o. time.

Below an overview of the assessment of the GIS-datasets originating from Reid *et al.* (2003) is given. In summary it is sufficient to say that of eleven available marine mammal species, only three are currently present inside the case study area to be considered for inclusion: harbour porpoise, white-beaked dolphin and minke whale. After further investigation a conclusion is reached that there are insufficient grounds to include these species in the present study. For more information and background, please the reader is referred to the text box below.

Selection of species from Reid *et al.* (2003)

Cetaceans (whales and dolphins) have been considered for inclusion in the case study, based on the availability (through CEFAS) of a set of GIS-datasets originating from Reid *et al.* (2003).

From the range of available marine mammal species, eleven where deemed inappropriate for inclusion in the case study due to their very limited occurrence within the case study area. These species may be encountered there, but the central and southern North Sea are not areas that are of true importance for them. The species not included for this reason are:

- Atlantic white-sided dolphin, *Lagenorhynchus acutus*
- Beaked whales, *Mesoplodon spp.*
- Fin whale, *Balaennoptera physalus*
- Humpback whale, *Megaptera novaeangliae*
- Long-finned pilot whale, *Globicephala melas*
- Northern bottlenose whale, *Hyperoodon ampullatus*
- Orca/ Killer whale, *Orcinus orca*
- Risso's dolphin, *Grampus griseus*
- Sei whale, *Balaenoptera borealis*
- Short-beaked common dolphin, *Delphinus delphis*
- Striped dolphin, *Stenella coeruleoalba*

From the species listed above some may become more abundant in the central and southern North Sea as a result of climate change. Most of the listed species have a distribution pattern indicative of a preference for colder waters and as a result these are not likely to increase their presence in the North Sea. The short-beaked common dolphin and the bottlenose dolphin (*Tursiops truncatus*) are species that are under current conditions more numerous in areas to the west and south and an increased presence of these species may be observed in the future. By extension to this with higher water temperatures the relevance of considering turtles may also increase for the North Sea. For three species numbers and distribution within the central and southern North Sea warranted further evaluation:

- Harbour porpoise, *Phocoena phocoena*
- Minke whale, Balaenoptera acutorostrata
- White-beaked dolphin, *Lagenorhynchus albirostris*

Harbour porpoise

For harbour porpoise, Reid et al. (2003) gives an estimate for the North Sea population of 280000 animals, with a further 36000 in the Skagerrak and Belt Seas. These numbers are based on the SCANS survey performed in July 1994. Citing sources from 2007 the Dutch ministry of Economic Affairs, Agriculture and Innovations gives an estimate of 270000 of the North Sea population [URL: http://mineleni.nederlandsesoorten.nl/get?page_alias=soort&sid=551 in Dutch].

A Belgian website (URL: http://bistrobeaufort.skynetblogs.be/archive/2007/03/14/dolfijnen-zijn-terug-in-de-noordzee.html) gives a reasonable estimate for 2007 of around 7000 harbour porpoise ending up as by-catch in fisheries across the North Sea. A number matching an estimate of 6000 deaths from by-catch given on a webpage from IMARES (URL: http://www.wageningenur.nl/nl/show/Pingers-tegen-bijvangst-bruinvissen.htm) with a reference to Vinther and Larsen (2004).

Based on these numbers harbour porpoise mortality from fisheries (as bycatch) would be estimated at more than 2%. A level above the 1.7% agreed upon under the ASCOBANS agreement (Haelters and Camphuysen, 2011). This source also states that there is little evidence of harbour porpoise bycatch in trawls (beam trawling and otter trawling) in the southern North Sea. The main gear types causing bycatch of harbour porpoise are static gears, especially gill and tangle nets.

As a result of these traits of harbour porpoise bycatch, the inclusion of this sea mammal in this case study is seen as irrelevant. The type of fishery that mainly being considered and for which a dataset is available is based on trawled gears.

The impact of offshore wind development on harbour porpoises has been studied a.o. at Horns Rev I and Nysted (Teilmann *et al*., 2006), Horns Rev II (Brandt *et al*., 2011) and at OWEZ (Scheidat *et al*., 2011). During construction while pile driving is on-going there is a clear decrease of harbour porpoise activity in an area extending up to 20 nm away from the pile driving location. This effect last for up to 3 days (Teilmann *et al*., 2006). Once a wind farm becomes operational the abundance of harbour porpoise in the area recovers, but to different degrees. At Nysted levels remained lower than before, at Horns Rev I full recovery was observed and at OWEZ an increase of the wind farm area was noticed. Hypotheses on the reasons behind these different findings have been put forward and revolve around the attractiveness of the wind farm area relative to the surrounding area.

Impact is possible, but unless large scale simultaneous pile-driving is going to occur this is, the overall effect on this species is very likely low. For the present there is insufficient evidence and numerical data to estimate population level effects.

Minke whale

Reid *et al*. (2003) give an estimated population of 8500 Minke whale in the North Sea, based on SCANS data from 1994.

White-beaked dolphin

For this species Reid *et al*. (2003) indicate a population estimate of 7856 for the North Sea and Channel.

ICES (2013b) give information on bycatch for all three species (harbour porpoise, minke whale and white-beaked dolphin) and from that reporting minke whales appear to be bycaught only very occasionally. The other species are bycaught more often. Please observe that minke whale are also considerably less numerous than the other species. Most reported bycatches occur outside the North Sea, but elsewhere in the reporting area for the ICES Working Group on Bycatch of Protected Species. This is most likely a combination of higher abundance of the species elsewhere and higher use of fishing gears that are more prone to bycatch of cetaceans. In this respect static gears, e.g. gill nets are mentioned. A different source points to pelagic trawls as a possible problem, mainly with respect to minke whale (http://www.eurocbc.org/page120.html).

An estimate of ‘population level’ effect on has been attempted by ICES WGBYC (2013) for harbour porpoise, common dolphin, white-beaked dolphins and minke whales, but no conclusion was reaches. This was mainly due to the absence of usable effort data (of the fisheries).

Based on the observations made above a choice was made to also not pay specific attention to minke whale and white-beaked dolphins in this study. There is insufficient reliable information to properly place the possible influences of fisheries and offshore wind energy production into context.

Appendix B. Sources of data used for the WINDSPEED-project.

Dataset	Country	Organisation	Contact
Benthos	North Sea	IMARES (http://www.imares.nl)	Jan Tjalling van der Wal; Jan_Tjalling.vanderWal@wur.nl; +31 317 4 87147
Birds	North Sea	IMARES (http://www.imares.nl)	Mardik Leopold; Mardik.Leopold@wur.nl; +31 317 4 87097
Fish (species richness)	North Sea	IMARES (http://www.imares.nl)	Remment ter Hofstede; Remment.terHofstede@wur.nl; +31 317 4 87091
Fishery effort	Belgium	Instituut voor Landbouw- en Visserijonderzoek Institute for Agricultural and Fisheries Research (ILVO) (http://www.ilvo.vlaanderen.be)	undisclosed
Fishery effort	Denmark	Danmarks Tekniske Universitet, Institut for Akvatiske Ressourcer Technical University of Denmark, National Institute for Aquatic Resources (DTU-Aqua) (http://www.aqua.dtu.dk)	undisclosed
Fishery effort	England & Wales	Centre for Environment, Fisheries and Aquaculture Sciens (Cefas) (http://www.cefas.co.uk)	undisclosed
Fishery effort	Germany	Johann Heinrich von Thünen-Institut Federal Research Institute for Rural Areas, Forestry and Fisheries (http://www.vti.bund.de)	undisclosed
Fishery effort	Netherlands	IMARES (http://www.imares.nl)	Floor Quirijns; Floor.Quirijns@wur.nl; +31(0)3174 87190
Fishery effort	Norway	Havforskningsinstituttet Institute of Marine Research (IMR) (http://www.imr.no)	undisclosed
Fishery effort	Scotland	Fisheries Research Services, since 01-04-2009 part of Marine Scotland, a Directorate of Scottish Government (http://www.scotland.gov.uk/marinescotland)	undisclosed
Fishery effort	Sweden	Fiskeriverket Swedish Board of Fisheries (http://www.fiskeriverket.se)	undisclosed
Nature conservation	Belgium	Beheerseenheid van het Mathematisch Model van de Noordzee Management Unit of the North Sea Mathematical Models (http://www.mumm.ac.be)	info@mumm.ac.be; +32 (0)2 773 21 11

Nature conservation	Denmark	By- og Landskabsstyrelsen, Miljøministeriet Agency for Spatial and Environmental Planning, Ministry of the Environment (http://www.blst.dk)	blst@blst.dk; +45 72 54 47 00
Nature conservation	Germany	Bundesamt für Naturschutz (BfN) (http://www.bfn.de)	Ursula Euler; Ursula.Euler@bfn.de
Nature conservation	Netherlands	IMARES (http://www.imares.nl)	Jan Tjalling van der Wal; Jan_Tjalling.vanderWal@wur.nl; +31 317 4 87147
Nature conservation	Netherlands	Rijkswaterstaat (http://www.noordzeeloket.nl)	Aad de Ruijter; Aad.de.Ruijter@rws.nl
Nature conservation	Norway	Direktoratet for Naturforvalting Directorate for Nature Management (http://www.dirnat.no)	postmottak@dirnat.no; +47 73 57 05 00
Nature conservation	United Kingdom	Joint Nature Conservation Committee (JNCC) (http:/www.jncc.gov.uk)	comment@jncc.gov.uk; +44 (0) 1733 562626