

CHAPTER 2



Monitoring offshore wind farms in the Belgian part of the North Sea: Setting the scene

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Offshore wind farms are expected to contribute for about 43% of the Belgian 2020 targets for renewable energy. Today, 109 turbines are operational in the Belgian part of the North Sea. In the next few years, several hundred of turbines will be up and running. With 238 km² reserved for offshore wind farms, major ecological impacts may however be expected. These impacts both positive and negative, triggered an environmental monitoring programme focusing on various aspects of the marine ecosystem components, but also on the human appreciation of offshore wind farms. This report targeting marine scientists, policy makers and managers, provides an overview of the major scientific achievements of six years of monitoring.

OFFSHORE WIND FARMS IN BELGIUM

The European Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources in the internal electricity market, imposes a target figure for the contribution of the production of electricity from renewable energy sources upon each Member State. For Belgium, this target figure is 13% of the total energy consumption, which must be achieved by 2020. Offshore wind farms in the Belgian part of the North Sea (BPNS) are expected to make an important contribution (ca. 43%, assuming 2000 MW installed capacity by 2020) to achieve that goal.

With the Royal Decree of 17 May 2004, a 264 km² area within the BPNS is reserved for the production of electricity from water, currents or wind. It is located between two major shipping routes: the north and south traffic separation schemes. In 2011, the zone was adjusted on its Northern and Southern side in order to ensure safe shipping traffic in the vicinity of the wind farms. After this adjustment the

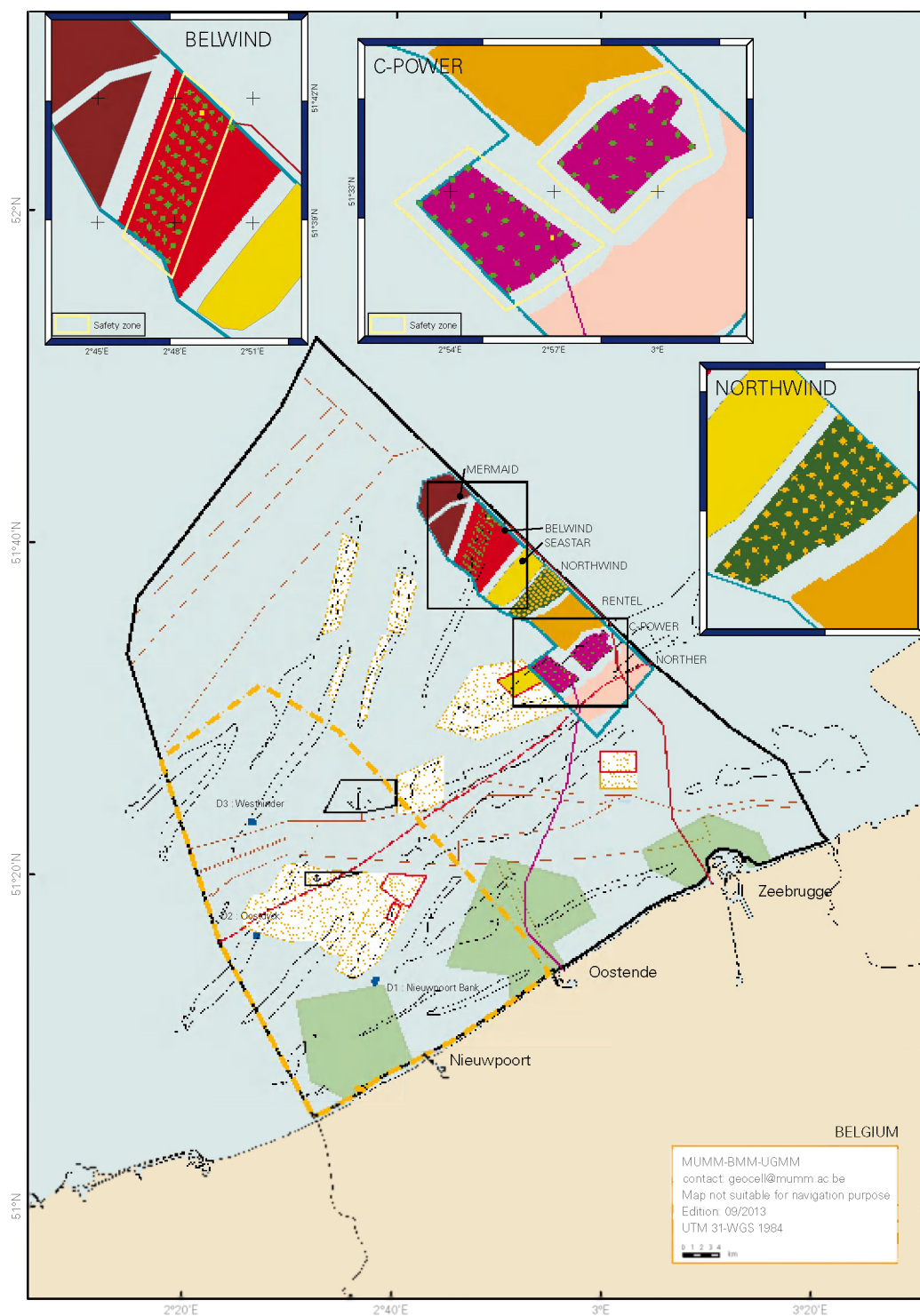
total surface of the area amounted to 238 km².

Prior to installing a wind farm, a developer must obtain (1) a domain concession and (2) an environmental permit. Without an environmental permit, a project developer is not allowed to build and exploit a wind farm, even if a domain concession was granted.

When a project developer applies for an environmental permit an administrative procedure, mandatory by law, starts. This procedure has several steps, including a public consultation during which the public and other stakeholders can express any comments or objections based on the environmental impact study (EIS) that is set up by the project developer. Later on during the permit procedure, the Management Unit of the North Sea Mathematical Models (MUMM), a Scientific Service of the Operational Directorate Natural Environment (OD Nature) of the Royal Belgian Institute of Natural Sciences gives advice

on the acceptability of expected environmental impacts of the future project to the Minister responsible for the marine environment. MUMM's advice includes an environmental impact assessment (EIA), based on the EIS. The Minister then grants or denies the environmental permit in a duly motivated Decree.

The environmental permit includes a number of terms and conditions intended to minimise and/or mitigate the impact of the project on the marine ecosystem. Furthermore, as required by law, the permit imposes a monitoring programme to assess the effects of the project on the marine environment. At present, five projects were granted a domain concession and an environmental permit (from South to North: Norther, C-Power, Rentel, Northwind & Belwind). Two additional projects were granted a domain concession, one of which has submitted its application to obtain an environmental permit in summer 2013 (Table 1).



Human activities in the Belgian marine area

Belgian continental shelf	Export cable Belwind
Territorial sea limit	Export cable C-Power
Anchorage area	Reference zone for Wind farm monitoring
Navigation route	Mineral resources extraction zone
Area reserved for electricity production	Zone closed for mineral resources extraction
Operational wind turbine	Mariculture area
Turbine under construction	Site of Community Importance (Habitat Directive) "Vlaamse banken". New Special Area of Conservation
Offshore transformer station	Special Protection Area (Birds Directive)

Table 1. Overview of wind farms in the Belgian part of the North Sea (situation on 30th of September 2013)

*number of turbines and/or total capacity still to be decided

**20 MW wave energy

Project		Number of turbines	Capacity (MW)	Total capacity (MW)	Concession obtained	Environmental permit obtained	Status
C-Power	phase 1	6	5	325	YES	YES	Phase 1 completed in 2009
	phase 2&3	48	6.15		YES	YES	Entire wind farm completed in 2013
Belwind	phase 1	55	3	330	YES	YES	Phase 1 completed in 2011
	phase 2	55	3		YES	YES	Phase 2 construction foreseen to start in 2014
	demo	1	6		YES	YES	Alstom Haliade demo turbine installed in 2013
Northwind		72	3	216	YES	YES	Construction ongoing
Norther		47 – 100*	3-10	258 – 470*	YES	YES	Construction foreseen to start in 2014
Rentel		47 – 78*	4-10	289 – 468*	YES	YES	Construction foreseen to start in 2016-2017
Seastar		41*	4-10	252 – 540*	YES	NO	Construction foreseen to start in 2016-2017
Mermaid		75*	6*	450*+ 20**	YES	NO	No information



C-Power's onshore construction site of the gravity based foundations in Ostend.

TIMELINE WIND FARMS DEVELOPMENT

The C-Power project is located on the Thorntonbank sandbank, located at 27 km off the Belgian coast. In 2008, C-Power started with the construction of the first phase of its project, i.e. six turbines on gravity based foundations (GBF). A GBF is a hollow, concrete structure that is filled with sand once it is placed on the seabed. Due to its weight, it remains stable. Before the GBF can be placed, the seabed needs to be prepared to create a flat surface on dense sand.

2008



Transport of a gravity based foundation from the port of Ostend to the C-Power site at the Thorntonbank.



Assembly of a C-Power phase 1 turbine on the Thorntonbank.

2009

The six turbines of C-Power's first phase were commissioned and producing electricity by May 10th, 2009.



Phase 1 turbines on the Thorntonbank.

Pile driving of monopiles (MP) for the Belwind project on the Blich Bank started on September 8th 2009. The 56th and last monopile of the first phase was installed on February 5th 2010.

2010



Piling vessel (with red and white hammer) at the Belwind site on the Blich Bank.

A transition piece (TP) was installed on every Belwind monopile. The TP makes the connection between the MP and the wind turbine. In 2010, Belwind installed 55 wind turbines and one offshore high voltage station. The entire phase 1 of Belwind was fully operational from December 31st 2010 onwards.



Belwind Phase 1 wind turbines on the Blich Bank.

The construction of phase 2 and 3 of the C-Power project (i.e. 48 turbines and one offshore transformer station) started in spring 2011. The foundation type for the phase 2 and 3 turbines is different from the pilot phase since jacket foundations, instead of the GBFs, were installed. These foundations consist of a steel jacket with four legs. The foundations were installed using the pre-piling concept: four pin-piles were driven into the seabed and the legs of the foundation were grouted on the pre-piles.

2011



Phase 3 jacket installation at the C-Power site.



The C-Power offshore transformer station was installed on March 17th, 2012. On the background the six phase 1 turbines and ongoing jacket installation.

The construction of the Northwind project on the Lodewijk-bank started in spring 2013. The wind farm is expected to be fully operational by spring 2014.

2012



Vessel on its way to the Nortwind site on the Lodewijk-bank with two monopiles and two transition pieces.

In the summer of 2013 the entire C-Power wind farm was finalised and producing energy. The wind farm was officially inaugurated on September 17th, 2013.

2013



Partial view of the C-Power wind farm.

OFFSHORE WIND FARM MONITORING AND RESEARCH STRATEGY

The monitoring programme started in 2005 with the investigation of the pre-impact condition of the ecosystem and the search for appropriate reference sites, but it was continued only from 2008 onwards when the first six wind turbines were installed onto the Thorntonbank. The monitoring programme targets physical (i.e. hydro-geomorphology and underwater noise), biological (i.e. hard substratum epifauna, hard substratum fish, soft substratum macrobenthos, soft substratum epibenthos and fish, seabirds and marine mammals), as well as socio-economic (i.e. seascape perception and offshore renewables appreciation) aspects of the marine environment. MUMM coordinates the monitoring and covers the socio-economic aspects of the monitoring. OD Nature further adds its expertise in hydro-geomorphology, underwater noise, hard substratum and non-indigenous epifauna, marine mammals and radar detection of seabirds. Further collaborations complete the necessary expertise in the following domains: seabirds (Research Institute for Nature and Forest), soft substratum epibenthos and fish (Institute for Agricultural and Fisheries Research), soft substratum macrobenthos, hard substratum fish (Marine Biology Research Group, Ghent University), above water noise (INTEC, Ghent University), seabed morphology (IMDC) and seascape (Grontmij).

With the monitoring programme, MUMM and its partners (1) assess the extent of the anticipated impacts on the different aspects of the marine ecosystem and (2) aim at revealing the processes behind these impacts. The first objective is basically tackled through the basic monitoring, focusing on the *a posteriori*, resultant impact quantification, while the second monitoring objective is covered by the targeted or process monitoring, focusing on the cause-effect relationships of *a priori* selected impacts. As such, the basic monitoring deals with observing rather than understanding impacts and hence leads to area-specific results, which might form a basis for halting activities. In this study, basic monitoring generally follows a before-after, control-impact or BACI design, in which ecological changes at the impact site are compared with the ecological condition before the impact and in non-impacted reference or control sites. Targeted monitoring on the other hand deals with the understanding of the processes behind the impacts of a selected set of hypothesised cause-effect relationships highly relevant to the wind energy sector. This step is not only a prerequisite for an effective regulatory application, but also permits (1) current and future impact mitigation, (2) better prediction of future impacts, as well as (3) moving away from site-specific observations to more generic knowledge. More details on this topic can be found in Degraer and Brabant (2009).

SIX YEARS OF MONITORING AND RESEARCH

In addition to a set of early scientific reports presenting the baseline condition at future impact and reference sites (De Maerschalck et al., 2006; Henriët et al., 2006; Vanermen et al., 2006), an overview of the major achievements of the monitoring programme has been presented in a series of yearly published, integrated reports.

In 2009 (Degraer and Brabant, 2009), we reported on the lessons learnt and recommendations from the first two years of environmental monitoring. This report more specifically evaluated the appropriateness of the selected reference sites and reference conditions for both the C-Power and the Belwind projects. It further introduced the various environmental data under surveillance, including a preliminary evaluation of the impacts linked to the construction of the first six turbines at the Thorntonbank. Its main importance however is found in its advices for future monitoring at the level of technicalities, scientific design, as well as research focus and strategies.

Degraer et al. (2010) then focused on the early and/or localised environmental impacts of the GBF wind turbines (C-Power) and/or monopiles (Belwind), as well as on the natural spatio-temporal variability (i.e. dynamic equilibrium). Early impacts were detected for the geophysical environment of both the GBF wind turbines at the Thorntonbank and the monopile wind turbines at the Bligh Bank, the establishment of hard substratum biota on and close to the GBF wind turbines at the Thorntonbank, and the social attitude towards offshore renewables. The natural spatio-temporal variability was investigated for the soft

substratum macrobenthos, soft substratum epibenthos, soft substratum fish and marine mammals.

In 2011 (Degraer et al., 2011), a selection of targeted monitoring results was presented for the first time, from which we attempted to construct a hypothesis-driven impact scenario, including presumed cause-effect relationships between the various ecosystem components. The integration of the monitoring findings obtained so far, already allowed for some preliminary speculation on the long-term impact processes within the Belgian wind farm zone. Those were a prolonged organic enrichment of a naturally relatively poor environment, an increased food availability for epibenthic and fish predators and the improved seabird and marine mammal habitat quality. The Benthic Ecosystem Quality Index (BEQI) was further applied to evaluate the deviation in macrobenthic density, number of species, species composition and biomass between the benthic data collected in the impact area and the reference area, both from the period before and after the construction of the first wind turbines.

The 2012 report (Degraer et al., 2012) continued building on a common understanding of the environmental impacts of offshore wind farms. This included the cause-effect relationships of observed impacts within the benthos, a strengthening of the visual detection of impacts on seabirds and getting prepared for going offshore with the bird radar, and a quantification of harbour porpoise *Phocoena phocoena* disturbance by piling activities.

THIS REPORT

This report finally presents an integrated overview of all scientific findings of the Belgian offshore wind farm monitoring programme, with the specific aim of drawing lessons from these findings to optimise future monitoring programmes. The report as such covers a series of anticipated negative (Part I) and positive impacts (Part II), but also targets an understanding of the ecological processes behind observed impacts (Part III). Further considerations on context setting, nuancing and reflections on future monitoring are further presented in Parts IV and V, respectively.

Part I reports on the anticipated negative impacts, with:

- the disruption of a previously unspoiled seascape by offshore wind farms visible from the coast (Chapter 3); altered sediment characteristics and increased erosion of the natural sandy sediments around wind turbine foundations because of accelerating currents next to the foundations (Chapter 4);
- a major disturbance of seabirds because of avoidance and collision by seabirds (Chapter 5);
- increased construction and exploitation noise levels and the associated impact on marine mammals and fish (Chapters 6 and 7).

Part II targets a set of anticipated positive impacts, with:

- an enrichment of the soft-substratum macro-, epibenthos and fish as a result of e.g. the exclusion of fisheries from the wind farms (Chapters 8, 9 and 10);
- an attraction of fish by the introduced hard substrata (Chapter 11);
- an increased species richness because of the introduction of hard substrata (i.e. wind turbine foundations) and a consequent fouling by hard substrata invertebrates (Chapter 12).

Part III focuses on the results from the targeted monitoring, hence shedding a light onto cause-effect relationships behind the observed changes in the ecosystem (e.g. artificial reef, refugium and ecological trap effects; see Box), with:

- a local enrichment in soft sediment macrobenthos close to wind turbines (Chapter 13);
- a (possible) attraction of fish, seabirds and marine mammals as a consequence of habitat alterations (Chapters 14, 15 and 16).

Part IV aims at putting all findings into a wider context, as such nuancing anticipated positive and negative effects, with:

- an introduction to ecological pitfalls and unintended consequences in non-indigenous biofouling organisms, attracted fish and colliding seabirds (Chapter 17);
- a context setting of the locally observed increase in biodiversity and biomass (Chapter 18)

Part V finally reflects on the optimisation of the future offshore wind farm monitoring (Chapter 19).

While providing an overview of all major scientific findings, this report also serves as a feedback moment after six years of monitoring and research. Such feedback moment necessitates the attention not only of scientists, but also of the offshore wind energy sector as well as marine policy makers and managers, and the public at large. As its target audience hence is very wide we have chosen to restrict the scientific details to that level needed to comprehend our major findings. The report may and should hence be read as a non-specialist document. We fully understand some readers would however be interested in getting more detail, for which we refer to the integrated scientific reports introduced above (Degraer and Brabant, 2009; Degraer et al., 2010, 2011, 2012), all downloadable from www.mumm.ac.be. Alternatively, those readers may directly want to get in touch with the authors of the chapters, whose contact details may be found at page 239.



BOX:

The ecological hypothesis-derived terms artificial reef effect, refugium effect and ecological trap effect are commonly used throughout this report. The following definitions ascertain the reader to be clear on what is meant by these terms.

- **Artificial reef / reef effect (Langhamer, 2012)**

When introduced into the marine environment, wind turbines together with their associated scour protection, constitute an artificial reef which means that the surfaces are readily colonised by a typical and broadly predictable assemblage of organisms, reflecting zonation patterns observed in adjacent rocky shore communities. Although the scientific literature mostly agreed that there is likely to be a positive effect on fish and crabs, the extent and nature of the effect is heavily dependent on the nature of the reef created, the location, and the characteristics of the native populations at the time of introducing the artificial reef.

- **Refugium effect / no trawling zone (Langhamer, 2012)**

Establishing offshore wind farms facilitates the creation of no-trawling zones, covering hundreds to thousands square kilometres. As such, wind farms may prevent fisheries-induced stirring up of bottom sediments and loading suspended solids into the water column, as well as a direct reduction in vulnerable species, biodiversity, production and biomass in general. These no-trawling zones as such mitigate habitat losses and degradation. In these areas juvenile fish will have a higher chance to survive. Even older, larger fish will have increased survival rates and in this way offshore wind farms may contribute to a spill over effect. A consequent higher fishing pressure at the edge of the wind farms may counteract this anticipated positive effect.

- **Ecological trap (Robertson and Hutto, 2006)**

In suddenly altered ecosystems as is the case for the construction of offshore wind farms, ecological traps may arise. When an organism is attracted to, and preferably settles in a habitat with suboptimal conditions relative to other available habitats, it is caught in a so-called ecological trap. Ecological traps are thought to occur when the attractiveness of a habitat increases disproportionately relative to its value for survival and reproduction. Habitat choices are a consequence of natural selection and are based upon a number of ecological cues which indicate the quality status of a habitat. An ecological trap may occur when changes in the environment act to uncouple the cues used to assess habitat quality from the true quality of the environment.

