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Ecosystem impacts from offshore wind farms: Cross-border overview of lessons learnt from UK and Belgium.

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Abstract

The marine system is known for its complexity, especially when compared with other ecosystems. A combination of physical, chemical and biological components clearly influences the integrity of marine systems. The successful study and management of marine systems requires information from all its ecological levels.

Current monitoring programs of offshore wind farms (OWFs) collect information on the physical (e.g. 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) and socio-economical (i.e. seascape perception and offshore renewable appreciation) aspects of the marine environment. The majority of the current OWFs installations concentrate on monitoring a series of ecological receptors. This information can be used to support current monitoring programmes for advancing current knowledge on the effects of OWFs.

The need to produce energy from renewable sources has prompted countries such as the UK and Belgium to build a series of OWFs. Whilst these OWFs are operational, there is a demand to continue with new installations, which will require more turbines over larger areas. The operation and future of OWFs will need to be supported by robust monitoring programmes for evaluation and auditing the environmental impacts in the marine environment.

This work presents a review of commonalties and dissimilarities of ecological baseline and monitoring assessments of offshore wind farms in UK and Belgian waters. This work provides valuable information for regarding future licensing issues, future monitoring assessments as well as for fostering cross-border links for scientific collaborations in support of cost-effective OWF monitoring programmes.

Keywords: off shore wind farms, monitoring, benthos, and ecosystems.

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INTRODUCTION

The nations within and bordering the Oslo-Paris Commission (OSPAR) region are deeply committed to significant reductions in CO_2 emissions in the near future (Frid et al., 2011). The EU has set a target that 20% of energy used within the EU should be generated from renewable sources by 2020 (see Directive 2009/28/EC). Countries such as the UK and Belgium have set targets of 20% and 13% respectively, to generate electricity supply from renewable sources by 2020 (Renewable UK, 2011; Degraer et al., 2012). In addition to reducing CO_2 emissions, renewable energy generation could provide alternatives for minimising national dependencies on imported energy, increasing energy security and replacing diminishing domestic supplies of fossil fuels.

Marine renewable energy represents the most promising strategy to reduce carbon footprint worldwide (Lindeboom et al., 2011; Boehlert and Gill, 2011). Inevitably, there are some trade-offs associated with the adoption of such approaches, since the development of marine offshore wind farms (OWF) will create disturbance (e.g. during construction, operation and decommission phases) in the marine environment. At present, research conducted on the ecosystems of the North Sea areas has demonstrated that there may be some negative effects on protected species in the proximity of OWF areas. However, these effects are considered to be small, localised and temporary (Prins, 2010). Published studies have highlighted that effects on the seabed can occur during the construction phase. These effects can also be considered to be temporary and mitigation measures can be adopted to minimise these effects. For example, operational noise could be considered minor, although construction activities are known to possibly generate excessive impulsive noise levels ($L_{p\text{-}p}$) of up to 270 dB re 1 µPa (Norro et al., 2010, 2011) and are temporarily disturbing harbour porpoises *Phocoena phocoena* up to a distance of 22 km (Haelters et al., 2012). Harbour porpoises appear to be relatively sensitive to disturbance from vessels compared to other cetacean species (Thomsen, Laczny et al. 2006); (Koschinski 2008). Documentation of ship strikes on harbour porpoises is rare: only one confirmed mortality of a harbour porpoise has been documented where an individual was found with lacerations from a propeller in the UK (Kirkwood, Bennett et al. 1997).

Birds are an important ecosystem component and they can be susceptible to offshore maritime activities (injury, reducing breeding success and death) (Kershaw et al., 2012). The UK is home (breeding or over-wintering) to several species of seabirds of international importance, including over 50% of the biogeographical population of Manx shearwater, northern gannet, great skua and lesser black-backed gull (Langston 2010). Langston considered the potential effects on birds due to OWF development under Rounds 1, 2 and 3 (Langston 2010). The main potential risks are: collision mortality; disturbance or displacement leading to effective habitat loss; barriers to movement of migrating birds potentially increasing flight energy demands; disruption to functional links, for example between breeding and feeding areas; habitat change with associated changes in food availability; and the cumulative effect of these across multiple windfarms (Kershaw et al., 2012). Some seabirds, such as northern gannet *Sula bassana*, were found to avoid OWFs, while other species, such as sandwich terns *Sterna sandvicensis*, tend to be attracted (Vanermen et al., 2012).

A new OWF can also act as new habitat facilitating colonisation for benthic species. These new surfaces are suitable areas for ascidians, serpulids, hydroids, barnacles, mussels, algae and crustaceans (Whomersley and Picken 2003; Wilhelmsson and Malm 2008; Langhamer, Wilhelmsson et al. 2009) as well as (intertidal) non-indigenous species such as the marine splash midge *Telmatogeton japonicus*, extensive food resources and shelter for fish, e.g. cod *Gadus morhua* and pouting *Trisopterus luscus* (Kerckhof et al., 2011, 2012, Reubens et al., 2011). In absence offishing activity , epibenthic brown shrimps *Crangon crangon*, swimming crabs *Liocarcinus holsatus* or plaice *Pleuronectes platessa* are demonstrated to increase their size inside OWFs (Vandendriessche et al., 2011, 2012).

At present there are no examples of impact during the decommissioning phase of an OWF, but it is believed that similar impacts on benthic communities as those identified during construction will be observed (Gill 2005). There are, however, additional issues, such as the removal of long-term underwater structures from the seabed. This will modify the habitat, with repercussions for benthic species distribution and community structure. At the end of the wind farm’s life (approx. 25 years), it is likely that a hard-substratum benthic community will have established itself on the structures (Bacchiocchi and Airoldi 2003; Langhamer and Wilhelmsson 2009) .

Larger and/or multiple OWF projects may require consecutive construction phases for the installation of a number of cables and turbines with construction activities lasting over a period of several years, and consideration should be given to the prolonged effect of these recurrent activities. These ongoing activities may affect species and habitat recoverability. The habitat loss and destruction of substrate or temporary displacement of sediment will have implications on different habitats types.

Given the (anticipated) impacts, every country has developed a well defined licensing procedure, including demands for effect monitoring and auditing. The process to issue a permit for the development of OWF varies depending on the country and the main drivers to develop the areas. In the UK the Crown Estate issues leases for the seabed, and most offshore wind farms are regulated under the Infrastructure Planning Unit, which examine applications, leaving the final decision to the Secretary of State. Additionally, the new marine planning system being developed by the Marine Management Organisation (MMO) will also be important in determining suitable applications for wind farms. The MMO will decide applications for small wind farms. In Belgian waters, OWF developers first have to receive a domain concession within a delineated 238 km² wind farm zone from the Federal Public Service (FPS) Economy, after which they can apply for an environmental permit for the OWF from the FPS Environment. The latter environmental licensing procedure also includes the definition of the mandatory monitoring and auditing programme. There will be clear differences between different states on the licensing requirements when deciding and planning to develop an OWF. For the purpose of this manuscript, we will only briefly cover licensing issues associated with OWF developments. We do consider the commonalities and dissimilarities between the UK and Belgium procedures with an emphasis on biological monitoring programmes for OWF.

CASE STUDIES

We present two cases studies to illustrate the overall OWF process and to identify key issues for further consideration (Figure 1). We acknowledge that the OWF development covers several aspects (e.g. benthos, fish, mammals, noise, birds and coastal processes) and there is targeted monitoring that complies with these requirements in each country. For simplicity, we have focused on the biological aspect of the monitoring programmes. These two studies are described below:

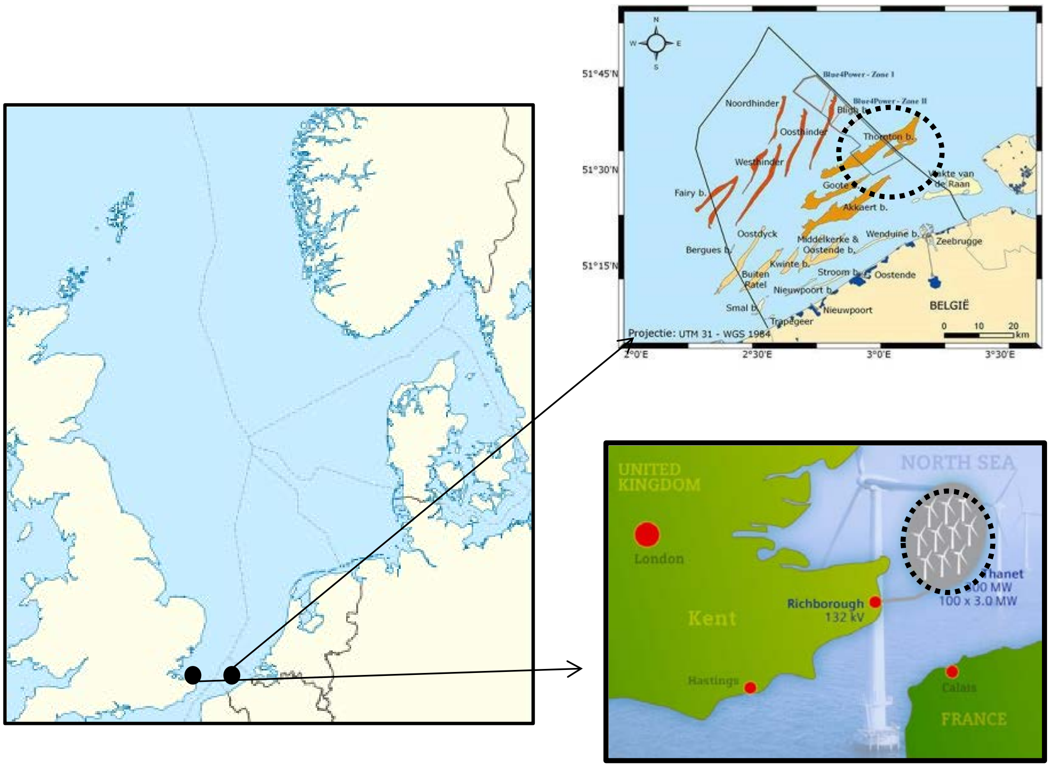

Figure 1. Location of study sites, Thanet and Thornton Bank Offshore Wind farms. Images extracted from Google images and Siemens.co.uk.

UK THANET OFFSHORE WIND FARM

The Thanet Offshore Wind Limited (TOW), a subsidiary of Warwick Energy Limited (WEL), was created to develop opportunities for energy generation from renewable resources in the Thanet area. TOW has been awarded the rights to develop an offshore wind farm in the Thames Estuary Strategic Environmental Assessment (SEA) area by The Crown Estate under Round Two of the offshore wind licensing arrangements. The TOW project is located 11.3km offshore from Foreness Point, the eastern most part of the Kent coastline. There are 100 Vestas V9 wind turbines installed. The output of the turbine chosen generated an output of 300MW. This is enough to provide electricity for 240,000 average homes, which will account for a significant proportion of the energy needs of East Kent.

The maximum height of the turbines is up to 150m (approx 500 feet) from sea level to the blade tip in the vertically up position and the minimum clearance is 22m (approx 70 feet) to the blade tip in the vertically down position. The spacing between turbines is 500m along rows and 800m between rows. The turbine nacelle, complete with three blades was mounted on a cylindrical steel tower, supported by a foundation fixed to the seabed. Due to the seabed conditions, water depth and environmental characteristics monopile foundations were chosen for this project. The wind farm also included an anemometry mast to collect data on wind speed and direction. The turbines were interconnected by a buried 33kV cable network and connected to an offshore substation platform where the voltage is stepped up to 132kV. Electricity was connected to shore by two export cables, which are routed to a landfall point at Pegwell Bay. The cables were buried to a depth of between 1m and 3m depending on localised seabed conditions. Grid connection was made via cables buried under the A256 Sandwich Road to the existing substation at the disused Richborough Power Station, from where power would be distributed via the existing local electricity network.

The development of the Thanet project has helped the UK move towards its goals by reducing emissions of CO_2 by approximately 36 million tonnes over its 40 year lifetime, when compared to generating the equivalent electricity from a coal fired power station.

Original data collection and surveys

Further to the findings of the scoping exercise and consultation with the statutory consultees, the following surveys were undertaken as part of the EIA.

- Geophysical survey to characterise the surface and subsurface of the seabed;
- □Marine biological survey including epi-fauna (on the surface of the seabed) and infauna (living in the sediments of the seabed);
- Fish surveys and observer trips with local fishing vessels;
- Activity survey of local fishermen;
- Intertidal survey of the seashore;
- Aerial and boat based bird surveys;
- Marine traffic survey;
- Seascape and visual character assessment;
- Terrestrial ecological survey to identify the main habitats and presence of any protected species.

BELGIAN C-POWER OFFSHORE WIND FARM

The C-Power project is located on the Thornton bank, located 27 km off the Belgian coast. Water depth in the concession area varies between 18 and 24 m. The C-Power concession area is divided into two subareas, these are areas A and B. Across both subareas at total of 54 wind mills will be installed. Phase I (30.5 MW), a pilot phase, consists of six wind mills in subarea A and the installation of the first 150 kV offshore cable. The six 5MW Repower turbines have been operational since May 2009. Phases II and III are ongoing and will each consist of 24 turbines of 6.15 MW. The total installed capacity of the entire wind farm will be 325 MW.
C-Power used gravity base foundations (GBFs) for its first phase. These GBFs are hollow, concrete structures that are filled with sand, upon installation onto the seabed. More detailed information can be obtained from Peire et al. (2009) and Brabant & Jacques (2010). The foundation type for the phases II and III wind mills were jacket foundations, consisting of a steel jacket with four legs. The foundations were installed using the prepiling concept: four pinpiles were driven into the seabed and the legs of the foundation were grouted on the pinpiles. The piles vary in length depending on the

water depth and range between 21 to 50 m. The piling activities of the Phases II and III started in April 2011 and lasted up to the end of August 2011. All jacket foundations were consequently installed by the first half of 2012. In late spring and summer 2012 a total of 30 turbines as well as the offshore transformation station and the second export cable were installed. The last 18 turbines will be installed in late spring 2013. Both power cables come ashore near the city of Oostende.

In the Thornton Banks EIS/EIA-procedure, similar surveys were undertaken as part of the EIA, these are listed below:

- Geophysical survey to understand the characteristics and features on the surface and subsurface of the seabed;
- Sediment transport and hydrodynamic modelling
- ☐Marine biological survey including sampling and analysis of organisms living in the sediments of the seabed, on the surface of the seabed and fish surveys;
- Boat based bird and marine mammal surveys;
- A study on the impact of the OWF on radar and inter-vessel communication;
- An Oil-spill risk study
- Seascape and visual character assessment and social acceptance study;

EIA process: Data collection and surveys

In the UK the need to undertake and Environmental Impact Assessment (EIA) for OWF is to primarily establish the suitability of a site for a wind farm. The EIA is a detailed process which encompasses a large body of evidence from a several disciplines (Ecology, Landscape, Noise, Aviation, Archaeology, Transportation and Construction). These different topics evaluate the characteristics of the environment and the likelihood of whether the resultant effects and changes in conditions are acceptable. Depending on the nature of the project, there will be different constraints associated with the development. A general overview of an EIA is presented in Figure 2.

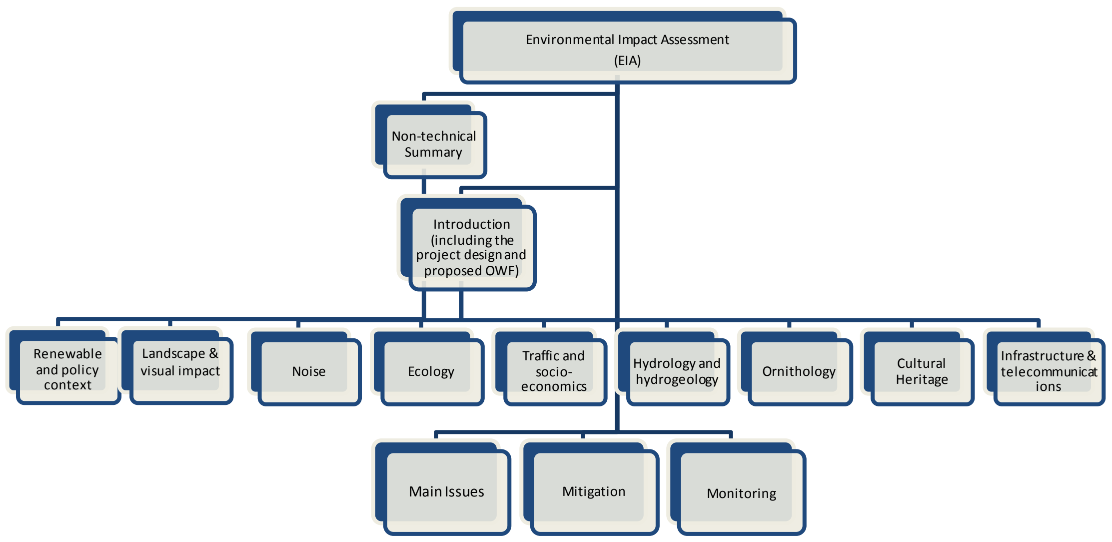

Figure 2. Schematic diagram displaying all of the stages that are considered in an EIA.

The EIA stages showed commonalities for both countries on the parameters considered (in an EIA/EIS) to document the environmental characteristics and their different ecosystem components.

As well as considering the stages of the EIA we have also included the overall process for a developer to apply for an environmental permit, these steps are summarised below (Figure 3).

Broadly, the overall process deals with a series of steps: i) scoping of the project, ii) the main effects expected from the development, iii) assessing the evidence, iv) public consultation and v) granting planning permission. In both countries, the regulation process to obtain consent for an OWF has common stages. These two processes are displayed below (Figure 3).

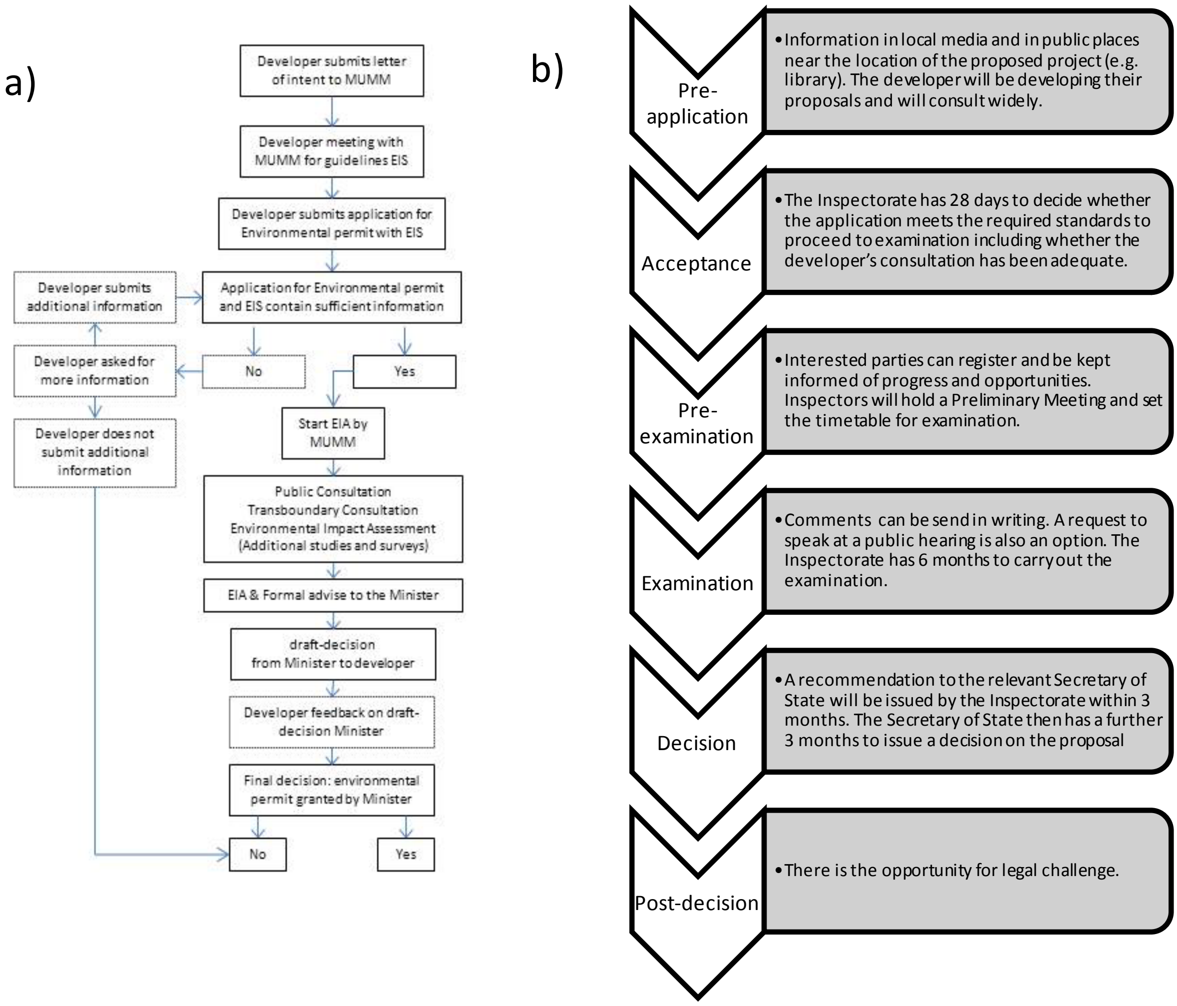

Figure 3. Examples of the stream-line consent for construction projects at (a) Belgium and (b) UK (adapted from the Planning Inspectorate (http://infrastructure.planningportal.gov.uk/wp-content/uploads/2012/04/Advice-note-8.1v4.pdf).

The EIA document also has to consider the monitoring requirements (as part of the post-construction) of an OWF. For both case studies we have identified the following monitoring surveys, which are part of the compulsory monitoring programme in UK and Belgium. The list presented below have similar aims, these are:

- Geophysical surveys to monitor sediment and bathymetry dynamics, including scour effects and power cable burial
- ☐Marine biological surveys, including sampling and analysis of organisms living (1) in the sediments of the seabed (macrobenthos) and on the surface of the seabed (epibenthos and benthic, demersal and bentho-pelagic fish) (2) on and near the windmill foundations and erosion protection layer (epifouling organisms and fish, respectively)
- Aerial surveys and passive acoustic monitoring (PAM) of marine mammals
- Boat-based and radar-based bird surveys;
- Seascape and visual character assessment;

RESULTS

MAIN DRIVERS UK AND BELGIUM INCLUDING SOME LICENSING ISSUES

In 2004 the Belgian government demarcated by Royal Decree a zone for the construction and operation of installations for renewable energy. OWF projects can request a concession for an area within this zone for a period of 20 years. Several projects compete for a specific concession area at this stage of the licensing.
The following criteria are taken into account when granting a concession to a specific project:

- The compatibility of the project with the Belgian goals for renewable energy
- The impact of the project on other licensed activities in the area
- The technical and economic quality of the project, including the use of best available technology
- The quality of the exploitation and maintenance plan
- The technical and financial provisions for the dismantlement of the installations

In addition to being granted a concession each project has to obtain an environmental permit, persuant to the law on the protection of the marine environment (20 January 1999) and two Royal Decrees. Briefly, this legislation includes an environmental impact assessment (EIA) by the MUMM resulting in a formal advice to the Minister. This EIA is based on an environmental impact study (EIS) submitted by the applicant. In the framework of its evaluation the MUMM can, if necessary, carry out, or order additional studies and research. Projects are granted an environmental permit when no unacceptable impacts on the environment are expected.

At the time of licensing the Thanet project, licenses in the UK were issued under Part II of the Food and Environment Protection Act 1985 (FEPA) (subsequently replaced by the Marine and Coastal Access Act 2009) and were required for any construction activity within the marine environment or the deposition of material at sea (Walker, 2011). The aims of the FEPA Act were to:

- Protect the marine environment, and the living resources which supports and human health,
- Prevent interference with other legitimate uses of the sea.
- Minimise nuisance from the disposal of wastes at sea.

The Licensing Authority in England at the time was the Marine and Fisheries Agency (replaced by the Marine Management Organisation in 2009 in England and Welsh Government in Wales. In Scotland it is Marine Scotland and in Northern Ireland it is the Department of Environment. The licensing process under FEPA involved a thorough assessment of the likely effects of the work on the marine environment and the need for measures to mitigate impacts and/ or provisions for marine monitoring. The developer was responsible for providing as much information as possible in their FEPA application (project design, environmental effects, significant effects, the use of natural resources, etc.). On issuing a licence for the works a variety of conditions are attached and these are enforced by the Licensing Authority and any failure by the License Holder to comply with these can trigger legal action leading to prosecution if the license holder is culpable.

WHO IS DOING WHAT: COORDINATION AND PARTICIPATION

In the UK the monitoring was associated with license conditions for each developer. For the Thanet OWF, Vattenfall Wind Power (Vattenfall) Limited commissioned consultants at Royal Haskoning in 2004 to undertake an Environmental Impact Assessment (EIA) to gain the necessary consents for the construction, operation and eventual decommissioning of the wind farm. The EIA work for Thanet involved extensive consultation with more than one hundred statutory and non-statutory organisations. Royal Haskoning undertook detailed data collection and survey management, as well as an assessment of the potential impacts on areas including: archaeology, birds, fisheries, marine mammals, recreation and navigation. Following the award of consents, Royal Haskoning was appointed Environmental Liaison Officer (ELO) for the project and continues to provide consents advisory services to TOW and Vattenfall (http://www.royalhaskoning.co.uk/en-gb/Publication/Documents/projects/Thanet-Offshore-Wind-Farm.pdf). The regulator of this OWF is now the Marine Management Organisation (MMO). The monitoring report is reviewed upon MMO request by a core of advisors from different organisations (e.g. Cefas, JNCC and NE).

In the C-Power case study, the mandatory monitoring programme is clearly and officially outlined as part of the environmental permit. The Management Unit of the North Sea Mathematical Models (MUMM) is responsible by law for the coordination and execution of this programme. As a multi-faceted monitoring programme as presented here cannot be executed by a single research institute, MUMM however has the possibility to collaborate with other research institutes to complete its expertise. In the case of the C-Power monitoring, MUMM collaborates with the Research Institute for Nature and Forests (INBO, seabird expertise), the Research Institute for Agriculture and Fisheries (ILVO, epibenthos and soft substrate fish) and the Marine Biology Section of Ghent University (soft substrate macrobenthos). As such, MUMM coordinates the monitoring programme and specifically covers hydro-geomorphological aspects, underwater noise, hard substrate epifauna, radar detection of seabirds, marine mammals and socio-economic aspects. The scientific coordination of the monitoring programme includes the yearly integration of the findings into widely distributed reports and the yearly (adaptive) planning for the next year's monitoring needs. For the latter aspect, the monitoring programme has been detailed defined, yet allows for flexibility in case needed (e.g. new insights).

Knowledge exchange

The information collected as part of the monitoring programmes is funded by industry in the UK and Belgium. In some instances the information could be made available upon request but since this information has been collected and paid with commercial funds, the information may be subject to restriction and/or embargo. Requests for the Thanet EIA are directed to the industry and their consultants involved in the project. The industry maintains an active web portal with information on the project and a non-technical summary informing the general public of the developments of the project. The Marine Management Organisation will receive the monitoring report and this document will be circulated between government advisors (e.g. JNCC, Natural England and Cefas), which will review and provide further comments for specific areas of expertise (e.g. coastal processes, fisheries, benthic ecology, conservation, archaeology etc.).

The C-Power environmental permit does not foresee any embargo on the (raw) data and knowledge gathered during the monitoring programme. The findings from the environmental monitoring of the C-Power OWF are published in yearly integrated reports (see Degraer et al. 2009, 2010, 2011, 2012). These reports serve an open communication both within the scientific community and with the OWF industry. They are used to fine tune the research programme in a transparent manner by sharing all information available on a yearly basis. These publications are further freely and widely spread to interested parties within and outside Belgium and are freely downloadable from MUMM's website (www.mumm.ac.be). The environmental permit further mandates the organisation of a scientific conference, during which all knowledge gathered during the first six years of environmental monitoring are to be presented in an integrated manner. This first comprehensive overview and evaluation of findings, which will take place in autumn 2013, will be the basis for a further planning of the monitoring programme.

MONITORING FOCUS

The Thanet project is equally committed to social acceptance and has provided benefits to the local area (e.g. creation of new jobs, spending resources in the local suppliers, contractors and services), as well as booting the local tourism for the area bringing visitors to both onshore and offshore wind farm developments. On the other hand, the monitoring programme for this area has focused on several aspects ranging from benthic ecology, birds, fish, marine mammals and scour effects resulting from the turbines.

Next to social acceptance and hydro-geomorphology, the C-Power monitoring programme comprises a multitude of biology-focused aspects. The impacts on the original and hence natural soft substrate benthic ecosystem are researched at the level of the macrobenthic infauna, the epibenthic fauna as well as benthic, demersal and bentho-pelagic fish. Epifouling macro-invertebrates and fish are investigated at the introduced, artificial hard substrates, while the whole of impacts on seabirds and marine mammals is taken care of as well.

An example for benthic monitoring is provided in Table 1 to show targeted monitoring.

Table 1. Summary table with the synergies and different issues associated with the two developments for the study sites.

Site	***Aims of the survey***	***Key concerns***
Receptor		
Thanet OWF	*Monitoring monopile and adjacent sediments*	• *Assessing faunal colonisation of monopiles and scour effects assessment* • *Sabellaria spinulosa aggregations Assessment*
	Monitoring fish presence and the effects of underwater noise	• *Effect of exclusion and displacement of fisheries* • *Effects of noise during construction (pilling)*
	Marine mammals	• *Marine mammals monitored but not considered to be an issue in the area*
	Seabirds	• *Attraction-avoidance* • *Collision risk*
Thornton Bank OWF	*Monitoring the surrounding sediments around monopiles*	• *Organic matter issue on soft sediment s* • *Effect of exclusion and displacement of fisheries*
	Monitoring epifauna and fish on artificial hard substrates	• *Proliferation of non-indigenous species* • *Changes in food availability for fish* • *Attraction-production of fish*
	Underwater noise and marine mammals	• *Range of disturbance* • *Repopulation speed*
	Seabirds	• *Attraction-avoidance* • *Collision risk*

MONITORING DESIGN

For evaluating and auditing the environmental impacts of offshore wind farms, the environmental permit includes a monitoring programme to ensure (1) the ability to mitigate or even halt the activities in case of extreme damage to the marine ecosystem and (2) an understanding of the environmental impact of offshore wind farms to support policy, management and design of future offshore wind farms.

For the C-Power project, the former objective is basically tackled through the baseline monitoring, focusing on the *a posteriori*, resultant impact quantification, while the latter monitoring objective is covered by the targeted or process monitoring, focusing on the cause-effect relationships of *a priori* selected impacts. As such, the baseline monitoring deals with observing rather than understanding impacts and hence leads to area-specific results, which might form a basis for halting activities. Targeted monitoring on the other hand deals with the understanding of the processes behind the impacts and hence leads to more generic results, which might form a sound basis for impact mitigation. For more details on baseline and targeted monitoring we refer to Degraer & Brabant (2009). Each biology-focused aspect is covered by a baseline and a targeted monitoring programme. While the baseline monitoring is executed as prescribed by the environmental permit, especially the targeted programme allows for the flexibility needed to accommodate for new monitoring needs. The baseline monitoring follows a classic BACI design for the natural soft substrate benthos, the biofouling community, as well as for seabirds and marine mammals. Targeted monitoring of the natural soft-sediment benthos so far focused on the impact of local organic enrichment of the sediment and size-spectra of dominant epibenthic and fish species, while the hard substrate communities were investigated at the level of non-indigenous species and attraction-production hypotheses for fish. For seabirds, species-specific flight altitude frequencies were set up, while for marine mammals, the distance of harbour porpoise disturbance by piling activities was empirically modelled.

In the UK the new Marine and Coastal Access Act aims to achieve clean, healthy, productive and biologically diverse oceans and seas. This vision will enable the UK to better protect the marine environment and establish a more integrated planning system for managing our seas, coasts and integrated framework for regulation enforcement. Monitoring of OWF developments is required as part of the licensing process , any decisions made by the Marine Management Organisation (MMO) have to be based on sound scientific evidence and this information is obtained by a robust monitoring. Since Wind farms are considered to be still relatively new technology, with some projects still changing and improving their current design and methodologies, there is a clear need to design a fit for purpose monitoring programme. For example the marine ecology of the area is considered to be a typical part of the Southern North Sea with common and widespread organisms. However, the presence of the polychaete *Sabellaria spinulosa* has been recorded in the vicinity of the area. Under certain conditions this polychaete worm is known to form reef like structures which are important for marine life. *S. spinulosa* when found forming reef areas, is protected as it is an Annex I specie under the Habitats Directive. Therefore the monitoring has concentrated some specific efforts on recording the presence/absence and extent of this polychaete in the area.

NEW DEVELOPMENTS

The UK has announced the locations of new OWF developments known as 'Round 3'. These new developments will bring additional challenges for industry and legislators. The new OWFs will be in deeper areas and will have an increased distance from the shore, so there will be new challenges associated with data collection in larger offshore areas and for designing an effective monitoring programme to incorporate all the new issues of scale or multiple pressures exerted from larger and sparse turbine areas. Additionally there is a new consenting landscape process and regulatory environment associated to these new developments.

In 2002, C-Power applied for the construction and exploitation of an OWF on the Wenduinebank, about 10 km from the coast. No areas dedicated for OWFs existed at that time in Belgian waters. This OWF never succeeded in receiving an environmental permit and the plan was abandoned in 2003. The Royal Decree of 17 May 2004 then delineated a zone for the production of electricity from water, current and wind in the Belgian part of the North Sea (BPNS), the so called windmill zone. Since 2004 four companies, C-Power amongst them, were granted a domain concession and an environmental permit to build and exploit an offshore wind farm. The C-Power OWF was the first wind farm fully licensed and operational in Belgian waters. By September 2012 three other companies obtained a concession, but still have to get an environmental permit.

Another six wind farms are operational (Belwind), fully granted (Northwind and Norther) or in the pipeline (Seastar and Mermaid).

CUMULATIVE IMPACTS

In the UK, the potential scale of cumulative effects associated with Round 3 is far greater than in previous rounds. In many cases, cumulative effects will not be restricted to within Zones (intra-Zone) but may occur between Zones (inter-Zone) requiring developers and regulators to work together in their assessment and management. There is not only a need to assess projects on a specific basis but also have wider coordination between projects to provide some additional evidence to characterise some of the issues arising from a combination of activities. Similarly, other countries (e.g. Belgium, Germany and the Netherlands) will be facing similar challenges and to facilitate trans-boundary cumulative effects exchanges via early dialogue and discussions will help managers and regulators the opportunity to integrate knowledge from current and future OWF developments.

In Belgium, major cumulative impacts may be expected once all seven planned OWFs are built, as such covering a surface area of 238 km² with windmill interdistances of presumably only 450 to 1000 m. This OWF *sensu lato* will then occupy about 7 % of the BPNS. As at this moment there are no plans for other windmill zones in Belgian waters, other cumulative effects are to be sought in conjunction with the development of OWFs in neighbouring waters. This is particularly the case for the

Netherlands and UK. Kerckhof et al. (2011) for example, already mention the strengthening of the strategic positioning of non-indigenous hard substrate species as OWFs proliferate in the naturally soft sediment southern North Sea. Close interaction within the early planning phases and within the EIA procedure of OWF development in the neighbouring countries is hence taking place in Belgium.

DISCUSSION

The European Union (EU) is the world's largest maritime territory and marine resources which make a significant contribution to each Member State's economic prosperity and social well-being. The current legislative and policy goals aim to protect marine systems and, in particular, their sustainable usage. This is specifically exemplified by the European Marine Strategy Framework Directive (2008/56/EC; MSFD). The central goal of the MSFD is the maintenance of ecosystem biodiversity, goods and services by focusing on both the structure and function during assessments and management of impacts. When considering the MSFD for an OWF development, there are a series of uncertainties, therefore a precautionary approach is encouraged for developers. This principle obliges new developers undertaking projects at sea to ensure that there are no significant negative effects on the environment and protected species and habitats.

New legislation requirements are instigating governments to commit to the development of more OWFs, which will help to secure targets to generate energy from renewable sources. Current projects have indicated the adoption of specific approaches both for environmental licensing and to monitor the marine environment. From this paper, learning from two case studies from the UK and Belgium, key messages for an improved environmental licensing and impact monitoring can be drawn.

Environmental licensing

- From the case studies proposed in this manuscript it is evident that each country is subject to EU legislation whilst undertaking the developments. Each country in turn will also be obliged to comply with the national legislation and integrate the local requirements of the area and consider the appropriate consultation for the work and to obtain public support. There will be more challenges associated with the development itself (such as local characteristics of the area, structure and scale of the project, suitable strategy to provide the necessary evidence required for the project to go ahead). In the UK there challenges are broadly similar. One of the challenges that industry are facing at present is the changes to the planning system which have new challenges and regulations on the decision making process to enable the OWF developments

Impact monitoring

- Coordination and participation

A proper integration of the monitoring findings is key to maximise of the efficiency of the monitoring programme. In both case studies a central coordination has been implemented with MMO/MFA (UK) and MUMM (Belgium). Such central coordination, executed by a federal research institute, further ensures a maximum compatibility of the research. A central coordination does however not imply that all research has to be done by the coordinator. As is the case in both case studies, a research partnership was established to include the best available and compatible expertise. The central coordination of the monitoring programme should hence also take the responsibility to facilitate an efficient interaction between the multitudes of participating research institutes.

- Monitoring focus

The monitoring has to provide information on the main issues with a view of minimising the impacts in the marine environment. As such, a wide variety of receptor ecosystem components should be considered, as is done in both the UK and Belgian case study: all potentially impacted ecosystem components were included in the monitoring programme. Even though the same ecosystem components were included, we acknowledge the fact that specific monitoring questions may be site-specific depending on the local peculiarities of the project. In the Thanet OWF macrobenthos research is focused on *Sabellaria*, while this is not considered an important issue in Belgian waters.

The macrobenthos monitoring of the C-Power OWF rather focuses on the local organic enrichment in a naturally rather poor soft substrate environment.

- Monitoring design

In both cases, a monitoring plan has been presented as part of the environmental licensing procedure. Such monitoring programme is hence clearly defined *a priori*. The monitoring programme should however also allow for at least some flexibility to be able to accommodate for new monitoring needs (based on e.g. new insights). Such a flexible approach will ensure a continued update of the monitoring programme in order to achieve the most relevant information at a given time. Flexibility might be achieved through the inclusion of a targeted monitoring programme (as a counterpart of the baseline monitoring), focusing on specific hypothesized cause-effect relationships to understand, rather than only observe the impacts. A targeted monitoring plan is included in both case studies.

- Knowledge exchange

To allow for a real-time upgrade of knowledge ensuring an up-to-date incorporation of knowledge in OWF designs, a steady and continuous knowledge sharing is advised. Such knowledge sharing might be facilitated at the level of the raw data (as is the case for both example OWFs in this study) or at the level of interpreted monitoring data (as exemplified by the yearly production of an integrated monitoring report in Belgium). Such knowledge sharing should further be organized in a transparent manner, with a centralized data portal to use the information/data. MUMM serve as such centralized data portal. The MMO would probably hold most of this information for UK sources.

New developments

- New developments

In 2010, the UK announced the new round of offshore wind farms (Round 3-R3). These new opportunities have the capacity to provide an additional 32GW of electricity to the current energy targets. There will be new challenges which will have to be faced by developers and regulators. The UK industry have already identified some of the new issues associated with R3 developments, for example: i) monitoring in larger and deeper waters, ii) some licensing issues associated with the new Planning office, iii) adequate methodology for assessing cumulative effects, which is a legislatory requirement for R3 developments.

Between 2004 and 2004, in Belgium five applications for environmental permits for OWFs were submitted of which only was licensed. This was also the period during which the national legal framework for the sitting off OWF’s and the incentive scheme for renewable energy were altered repeatedly with the definition of a selected zone for the sitting of OWFs in the BPNS in 2004 as well as he fixing of an incentive scheme for the next 20 years when the next three application for OWFs could be licensed.

- Cumulative effects

Although EIA procedures are generally focused on individual OWF projects, as was the case for the Thanet and C-Power OWFs, there will be a need to assess the cumulative effects from multiple turbine foot prints as well as the effects resulting from other activities. Cumulative effects will gain increased attention as part of an integral assessment during a project and at more strategic level (Therivel and Ross, 2007). It is clear that more pressure on assessing this issue will arise as more OWFs are planned and /or constructed worldwide. These cumulative effects are not only to be considered within the country, but also in conjunction with OWF development in neighbouring countries.

Cumulative Effects Issues (CEI)

One of the main challenges facing offshore wind farm developers, regulators and conservation agencies is how best to undertake Cumulative Effects Assessment (CEA) of major offshore developments. This issue was raised by UK developers for the larger Round 3 OWF (Renewable UK, 2011). The potential scale of cumulative effects is far greater than in previous rounds. In many cases, cumulative effects will not be restricted to within Zones (intra-Zone) but may occur between Zones (inter-Zone) requiring developers and regulators to work together in their assessment and management. There will be a need to assess project on a specific basis but also a wider coordination between projects should provide some additional evidence to characterise some of the issues arising from multiple and single activities. The need to undertake CEI is a common issue for many developers. There is a need to facilitate trans-boundary cumulative effects exchanges via dialogue and discussion of case studies (e.g. Belgian, UK, German and Danish waters), helping to broaden the spatial extent and understanding of cumulative effect methodologies could be complement knowledge from current and for future OWF developments.

In the UK, decision-making regarding the cumulative impacts of Round 3 wind farms will require regulators to examine closely individual projects and their interaction with others (including non-renewable activities). Therefore, developing suitable approaches to assess cumulative impacts poses a greater challenge and a wider scope than previous projects.

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