CHAPTER 1

RELOADING BASIC ENVIRONMENTAL MONITORING OF OFFSHORE WIND FARMS IN BELGIUM: PHASE II

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SUMMARY

Lots of knowledge and expertise in relation to sampling technicalities and designs for offshore wind farm (OWF) monitoring were gained from the Phase I basic monitoring (2005, 2008-2016). Based on this knowledge, the sampling design for the basic monitoring, focusing on the detection of the long-term effects of OWFs, was revisited and discussed during a workshop with all scientists involved in the programme and invitees from the OWF industry. The workshop focused on (1) How to best deal with variability (natural, anthropogenically induced, spatio-temporal gradients)? (2) How to continue and optimise the basic monitoring programme? (3) How to plan the most appropriate sampling design for the basic monitoring programme? These issues were discussed in two subgroups covering the benthic and pelagic realm *sensu lato*; this to allow for a maximal

accommodation of the ecosystem component sampling programmes within each of the two realms. For each realm, distinction was made between variability that is of no interest in an offshore wind farm advisory setting (i.e. unexplained variation) that can either be excluded or that cannot be excluded, and variability in which we are interested and hence has to be an integral part of the monitoring design. All sources of variability were explored and categorized into one of these three types of variability. Possible sources of unexplained variation were excluded to the maximum by means of an adaptation of the sampling design. If this was not possible, these sources of variation were integrated in the monitoring programme and included as co-variables in the analysis. Management-relevant sources of variability in the data (i.e. benthic realm: e.g. distance to the coast, sedimentology, foundation type; pelagic realm: e.g. distance to the coast, seasonality) were used as explicit drivers for restructuring the monitoring programmes. An overview of the adapted monitoring programme for the benthic and the pelagic realm is presented.

1.1. INTRODUCTION

The first monitoring activities in the framework of the impact assessment of offshore wind farms in the Belgian part of the North Sea (BPNS) started in 2005. The objective was to gather reference data and to identify appropriate reference areas. The impact monitoring itself started in 2008, when the first six wind turbiness were constructed in Belgian waters. At first, the main focus was to come up with an appropriate methodology and monitoring design, to get at full speed from 2009 onwards. From then onwards, a distinction was made between basic and targeted monitoring. The basic monitoring is aimed at assessing the extent of the long-term impacts on the different aspects of the marine ecosystem and is therefore focusing on the *a posteriori*, resultant impact quantification. Targeted monitoring on the other hand deals with the understanding of the processes behind the impacts of a selected set of hypothesized cause-effect relationships highly relevant to the environmental impact assessment and is an important input for scientifically sound advice with regards to future projects. Only the basic monitoring programme is considered in this chapter.

The ministry responsible for the North Sea agreed to continue an integrated monitoring of the impact of offshore wind farms until at least 2023. Before the start of the second phase of the monitoring (2015 – 2023), the Operational Directorate Natural Environment (OD Nature) of the Royal Belgian Institute of Natural Sciences (RBINS) legally responsible for the execution of the monitoring programme, organised a workshop to evaluate how to optimise the basic monitoring programme. Over 30 participants from different research institutes, universities and the industry involved discussed for two days (28 – 29 October 2014) what has been achieved so far, what issues came up, how these could possibly be solved and hence, how to best continue the monitoring programme from 2016 onwards.

The workshop focused on (1) How to best deal with variability (natural, anthropogenically induced, spatio-temporal gradients)? (2) How to continue and optimise the basic monitoring programme? (3) How to plan the most appropriate sampling design for the basic monitoring programme? These issues were discussed in two subgroups covering the benthic and pelagic realm *sensu lato*. The benthic subgroup tackled the questions with regards to the ecosystem components sedimentology, macrobenthos and demersal fish. The pelagic subgroup covered (bentho-)pelagic fish, marine mammals, plankton, underwater sound as well as (sea)birds and bats.

The final conclusions allowed adjusting the Belgian basic monitoring programme where needed and set out the guidelines for the next phase of the monitoring. This chapter therefore aims at (1) providing an overview of basic monitoring programmes and their results until 2014; (2) scoping for a higher level of integration between the programmes; and (3) designing an enhanced basic monitoring programme for execution from 2015 onwards.

1.2. OVERVIEW OF THE MONITORED ECOSYSTEM COMPONENTS: 2005-2013

SEDIMENTOLOGY

The research of RBINS, OD Nature SUMO (Suspended Matter and Seabed Monitoring and Modelling) research team was aimed at quantifying the changes in turbidity and in the processes structuring the seabed during and after the construction of wind farms (turbine foundations and cable routes). Long-term measurements in combination with modelling techniques allowed predicting short- and long-term effects. Focus was also put on the dredging and sediment dumping activities related to the construction of the wind farms. Significant losses of sediment were observed, especially during the construction of the gravity based foundations.

Recent satellite images of turbidity wakes related to the wind turbines will contribute to quantifying the origin, dynamics and effects of these wakes. It is hypothesized that these wakes consist of recently accumulated biogenic deposits. This material will possibly be dispersed to a wider area due to these wakes.

SUMO is currently specializing in wake modelling and aims at using this knowledge in the impact monitoring of the wind farms. Because sediment wakes are produced by various anthropogenic activities, it is necessary to study the cumulative effects and to assess how the increase of fine sediments is buffered in the seabed, and how this is influencing the integrity of the bottom of the sea.

MACROBENTHOS OF THE SOFT SUBSTRATES

The research of the Marine Biology Research Group (Ghent University) focused on community structure, density, diversity and biomass of the macrobenthos of the soft substrates. Based on these data, the Benthos Ecosystem Quality Index (BEQI) was calculated, which is used by Belgium as an indicator within the Water Framework Directive and the Marine Strategy Framework Directive. The results showed that the macrobenthos (community composition, BEQI) is influenced by the disturbance due to the construction of a wind farm. This effect was however temporary. No large scale effects on the macrobenthic community could be observed during the operational phase of the wind farm. This might partially be explained by the fact that most samples were collected at the edge of the wind farms. Sampling locations inside the wind farms are therefore absolutely required in the next monitoring phase.

SOFT SUBSTRATE EPIBENTHOS AND ASSOCIATED FISH

The basic monitoring focused on wind farm effects and fringe effects of the redistribution of fisheries activities. This study executed by the Research Institute for Fisheries and Agriculture (ILVO), included several variables (density, biomass, diversity and species composition) of three ecosystem components (epibenthos, demersal fish and benthopelagic fish) in two seasons (spring and autumn), at two sandbanks (Thornton and Bligh Bank) and two sandbank habitats (sandbank tops and gullies). The density and length-frequency distribution of a few selected species were monitored in detail.

The data showed significant BACI-effects and significant effects within a specific year, both on the Thorntonbank and on the Bligh Bank. The number of ophiuroids (serpent stars) on the Bligh Bank in 2009 for instance, was significantly lower in the impact area compared to the reference area. Density of sole *Solea solea* was much higher in 2012 at the edge of the wind farm on the Bligh Bank, compared to the reference area. Dab *Limanda limanda* specimens were significantly smaller in the impact area on the Thorntonbank in 2012, than in the reference area.

Taking into account that the wind farms are relatively new and that monitoring of the epibenthos and demersal fish has only been possible for three years, it is of great importance to continue the monitoring of this ecosystem component.

EPIFAUNA OF THE HARD SUBSTRATES

The basic monitoring of the epifauna on the hard substrates executed by the Marine Ecology and Management section (MARECO) of RBINS, focused on the intertidal and subtidal (-15 m) parts of the turbine foundation and the rocks of the scour protection. Visual surveys and qualitative samples were used to study the intertidal, while video sequences and photographs completed quantitative samples in the subtidal and the collection of rocks from the scour protection. Both in Belwind and in C-Power, we always tried sampling at the same turbine. This was done seasonally.

The number of non-indigenous species (NIS) found in the intertidal samples was proportionally high (50%). The subtidal fouling community stabilised rapidly, with a dominance of a limited number of species and seasonal dynamics. The proportion of NIS in the subtidal samples was rather low. Differences in the fouling community between the Thornton Bank and the Bligh

Bank might be caused by the location of the foundation along the onshore-offshore gradient and/or by the type of substrate (concrete versus steel wind turbine foundations). The rocks of the scour protection harbor a larger number of species and this community is still developing.

HARD SUBSTRATE ASSOCIATED FISH

Hard substrate fish monitoring was conducted by UGent's Marine Biology Research Group between 2009 and 2012 at a gravity-based foundation (GBF) in the C-Power wind farm and focused on the community structure of the fish associated with the hard substrates. A hard substrate (shipwreck) and a soft substrate (sandbank) were assigned as control areas. The samples were collected every two weeks or every month with a fishing rod and by divers (visual observation; only at the GBF).

The samples, which contained 24 species in total, were dominated by Atlantic cod *Gadus morhua* and pouting *Trisopterus luscus*. The density of both species was much higher around the GBF compared to the shipwreck and the sandbank. The abundance of both species however varies seasonally, with highest densities in autumn. Cod specimens were mainly individuals from year class 1 and 2, for pouting this was year class 0 and 1. Year class 0 cod specimens were encountered in spring (May – June) in both C-Power and Belwind in several years. These individuals were circa 5 cm and therefore became benthopelagic only very recently.

SEABIRD

The impact of offshore wind farms on the density and distribution of seabirds was studied by the Research Institute for Nature and Forest (INBO) by means of a BACI design. Ship-based seabird surveys were conducted along fixed monitoring tracks through impact and reference areas following an international standard methodology. Three years of 'post-impact' monitoring on the Bligh Bank and surrounding areas showed that Northern gannet *Morus bassanus*, guillemot *Uria aalge* and auk *Alca torda* avoid the wind farm and that the numbers respectively decreased with 85%, 71% and 64%. The number of lesser black-backed gull *Larus fuscus* and herring gull *Larus argentatus* increased with a factor 5.3 and 9.5, respectively. The 'post-impact' monitoring on the Thorntonbank is currently ongoing.

The ecological motives explaining the attraction of certain species are unclear at this point, but aside from an increased availability of roosting locations, an increased food availability is a most plausible explanation. It is important to mention that the attraction of seabirds in the wind farms results in a higher risk of collision with the structures.

Aside from the seabird surveys, there is also a continuous monitoring of birds to study the impact of wind farms, making use of a bird radar (executed by MARECO). The goals of this study are (1) to assess to what extent wind farms act as a barrier to local and migrating birds and (2) to quantify the temporal variability (e.g. seasonal, diurnal) in bird fluxes through the wind farm area.

Based on the results of the visual surveys and the radar measurements we estimated the number of birds colliding with the turbines, using a mathematical bird collision risk model (CRM). The number of casualties per turbine per year [lower and upper 95% confidence intervals] in the wind farm at the Bligh Bank for the six most dominant seabird species is estimated at 1.8 [0.4; 12.5]. During one night of intense passerine migration, the CRM estimated 28 collision victims in the wind farm at the Thorntonbank.

UNDERWATER SOUND

The underwater sound level was measured by MARECO before and during the construction of the wind farms. The background level at these locations is about 100 dB re 1µ Pa SPL. During the construction of monopile and jacket foundation, steel piles are hammered into the seabed. This is creating excessive underwater sound levels, varying between 189 to 196 dB re 1µ Pa (zero to peak level (Lz-p), normalized at 750 m distance). These sound levels exceed the background level at a distance up to 70 km from the piling location.

MARINE MAMMALS

The monitoring of marine mammals executed by MARECO, is limited to the harbour porpoise *Phocoena phocoena*, as this is the only common species in the BPNS and it is regarded as most sensitive to underwater sound.

Three methods were used: Passive Acoustic Monitoring (PAM), Line Transect (aerial) Surveys (LTS) and (tested in 2014) Strip Transect (aerial) Surveys (STS; digital). PAM results in a (corrected) measure of presence – absence of porpoises at a certain location. LTS and STS render density and distribution figures. By the end of 2015, 3605 days of PAM data were collected (2010 – 2014 at four locations). 22 aerial surveys covering the entire BPNS were conducted. This resulted in valuable spatio-temporal data on distribution, number and presence of harbour porpoises. There are clear indications of disturbance during piling activities.

1.3. TOWARDS A BASIC MONITORING PROGRAMME PHASE II

DEALING WITH IMPACT-INDUCED VERSUS SPATIO-TEMPORAL GRADIENT-INDUCED VARIABILITY

To determine the ecological impact of an activity (i.e. offshore wind farm), the impact of that activity on a certain response variable (e.g. the density of a species) or multivariate community structure is investigated. The impact might be the change through time or the different evolution compared to a (not impacted) control or reference area. Both are often combined in ecological studies in a so-called BACI (Before-After Control-Impact) design. This allows comparing trends in the response variable.

Natural fluctuations of the response variable are causing variability in the data which is not linked to the investigated impact (i.e. statistical noise). Understanding the natural variability of the response variable is essential to include the right covariates, aiming to explain part of the data variability. Including the right covariates results in a lower chance of mistakenly interpreting a change in the response variable as an impact, while actually it is caused by an effect of (one of) the covariate(s). It also narrows confidence intervals and thus increases the statistical power.

The different sources of variation influencing the different ecosystem components were identified during the workshop. For instance, seabird density is influenced by e.g. seasonality, time of day, meteorological circumstances, the onshore-offshore gradient, fisheries activities, etc. All these co-variables are to be accounted for when assessing the impact of offshore wind farms on the seabird density.

WHICH VARIABLES INFLUENCE THE MARINE ENVIRONMENT AND HOW CAN THEY INFLUENCE THE IMPACT ASSESSMENT OF OFFSHORE WIND FARMS

Three types of variability were distinguished:

1. Variability in which we are not interested and which can be excluded with an appropriate sampling design (i.e. unexplained variation that can be excluded);
2. Variability in which we are not interested and which cannot be excluded (i.e. unexplained variation that cannot be excluded);
3. Variability in which we are interested in function of rendering advice in the framework of future wind farms and which should be covered by the basic monitoring programme.

The different sources of variation identified during the workshop, were allocated to one of these three groups and color-coded (1=red; 2=orange; 3=green; annex I).

Benthic Realm

Sources of unexplained variation to be excluded

For the benthic ecosystem components monitoring programmes several possible sources of unexplained variation in the data and therefore preferably to be excluded from the analysis, were identified. Seasonal variability and diurnal variability should be excluded because these do not contribute to our knowledge relevant to management advice. The same holds true for the variation linked to 'distance to a turbine'. These sources of variation can be excluded or at least reduced by adjusting the sampling design.

Sources of unexplained variation that cannot be excluded

An understanding of the effect of year-to-year variability, hydrodynamics, suspended particulate matter and other human activities do not contribute to our knowledge relevant to management advice but are difficult to exclude from the analysis and will therefore be adopted as co-variables in the monitoring programmes.

Variability relevant for advisory purposes

Other variables are to be included in the analysis, because understanding of this variability is of great importance with respect to rendering advice for future projects. For instance, the different types of foundations which are used at present (i.e. jacket, monopile and gravity-based foundations) should be incorporated in the sampling design. This is also the case for the configuration of turbines in the wind farm, as the orientation relative to the dominant tidal current is important for the resulting sediment transport and consequent ecological effects. The scale of the project has an influence on the hydrodynamics and sedimentology, and is an important variable in the way offshore wind farms act as a stepping stone for (non-indigenous) species living on e.g. the foundations and scour protection.

Sediment type and the nearshore-offshore gradient are also important variables to include, because the location of the wind farms are likely to trigger different impacts. For example, very different faunal communities are present along the nearshore-offshore gradient. It is essential to include this gradient in the sampling design to understand the impact of the OWFs on these different communities. Sediment type is an important variable determining the macrobenthic community structure.

The pelagic realm

variability to be excluded

The pelagic realm subgroup identified ‘diurnal variation’ and ‘distance to a turbine’ as variables causing variability in the data and which should be excluded. Diurnal variation is not of importance when assessing the impacts of OWFs for most ecosystem components and can easily be excluded by sampling only during daytime. For birds (night time migration) and bats however, diurnal variability is of course relevant and should therefore be included in the analysis. Distance to a turbine is considered less relevant in the basic monitoring, except for underwater noise impact assessment during piling activities.

Variability that cannot be excluded

Several variables linked to temporal variability (e.g. year-to-year variability, tidal variability) are included as co-variable in the analysis, because it is not possible (or very difficult) to exclude these. Other human activities are also considered as co-variables which cannot be excluded.

The wind speed affects the operational underwater sound, being louder at higher wind speeds because of the higher rotation speed of the turbines.

Variability relevant for advisory purposes

The following variables should be included in the analysis, because these do contribute to our management-relevant knowledge of OWF impacts: nearshore-offshore gradient, seasonality, time/effect interaction, wind farm configuration and scale, and wind speed. The nearshore-offshore gradient is of particular importance as there are different faunal communities living to the Southern part of the Belgian renewable energy zone (e.g. Norther concession area) and North of the Thorntonbank (e.g. Belwind concession area). This is the case for e.g. seabirds, fish, plankton, marine mammals, bats. The Belgian wind farm zone also crosses the boundary between the turbid coastal waters and the clearer offshore waters of the English Channel. Its impact on pelagic fish is unknown at present. Telemetry data of fish might provide insight here. The bird research should focus on both the nearshore community (e.g. sandwich tern, common tern, little gull) and the offshore community (e.g. auk, guillemot). This approach would also allow assessing the effect of the foundation type.

Seasonality is of great importance for both birds and pelagic fish, but for different reasons. The seabird community is very different in the different seasons: in May and June large numbers of terns reside in the area (mainly nearshore, birds directive Annex I species); in September and October there is intense migration of little gull (birds directive Annex I species); in November intense migration of northern gannet occurs (mainly offshore); in winter, large numbers of auks and guillemots reside in the area. This is why monthly seabird surveys are required year-round. Accounting for seasonality in the analysis is necessary to be able to give specific advice about the expected effects and possible mitigating measures, e.g. terns are sensitive to collisions but are mainly present nearshore. At present, we lack knowledge on the distribution of pelagic fish except for some anecdotic observations and assumptions (e.g. Atlantic horse mackerel is regularly seen in the wake of the turbines; hard substrates around the turbines are of importance for eggs and larvae of pelagic fish; sea bass is attracted by the turbine foundations; do wind farms have an effect on the distribution of herring and sprat?). To gain more knowledge, a year-round monitoring (catches with nets and/or sonar imagery) is required.

A time/effect interaction is of potential importance for birds and marine mammals. For instance, in Denmark habituation was observed in the response of red throated divers to wind farms. Just after the construction of the wind farm they avoided the park completely. After some years they came back to forage at the edge of the wind farm, possibly attracted by the higher food availability inside the wind farms. Similar habituation was also observed in the behavior of seals (recent telemetry study).

Wind farm configuration and scale are important variables to take in account in the impact studies on birds and fish. Large, connected wind farms might have a larger refugium effect for fish. For birds, this might create a barrier to migration if flight corridors are not foreseen. The configuration of turbines of a wind farm, more specific the number of turbines per unit surface area, is also influencing the impact on birds.

1.4. ADJUSTMENTS/IMPROVEMENTS OF THE SAMPLING DESIGN FOR THE BASIC MONITORING PHASE II

The relevant sources of variation for the benthic and pelagic ecosystem components are identified and we distinguished between variation we want to understand in function of rendering advice and variation we do not need to understand in such advisory context (i.e. sources of unexplained variation). The latter can partially be excluded by adjusting the sampling design. The part which cannot be avoided is adopted as co-variable. Taking account of all this, a sampling design including the number of samples and timing of sampling was developed.

ADJUSTMENTS/IMPROVEMENTS OF THE SAMPLING DESIGN FOR THE BASIC MONITORING PHASE II OF THE BENTHIC REALM

All possible combinations of substrate type and type of foundation, along the on-/offshore gradient are presented in tables 1 and 2, per ecosystem component (table 1: demersal fish, epibenthos of the soft substrate, macrobenthos and hyperbenthos; table 2: epibenthos of the hard substrate).

Table 1. Sampling options and choices for the benthic ecosystem components (except epibenthos of the hard substrate). GBF = gravity based foundation, JF = jacket foundation, MP = monopile.

Timing	Autumn													
On-offshore	Nearshore						Midshore				Offshore			
Sediment type	Fine?		Coarse		Cobble?		Coarse				Coarse			
Foundation type	unknown		Unknown		Unknown		GBF		JF		MP		JF	
Distance from foundation	Far	close	Far	close	Far	close	Far	close	Far	close	Far	close	Far	close
Demersal fish/ epibenthos soft sediments									•		•		o	
Macrobenthos								•	•	•	•	•	o	o
Hyperbenthos									•		•		o	

Table 2. Sampling options sand choices for the epibenthos of the hard substrate.

Timing	Autumn									
On-offshore	Nearshore		Midshore				Offshore			
Foundation type	Unknown		GBF		JF		MP		JF	
Depth (subtidal/in-tertidal)	Sub	Inter	Sub	Inter	Sub	Inter	Sub	Inter	Sub	Inter
Epibenthos hard sub			•	•	•	•	•	•	o	o

Legend	
	Not yet elaborated due to high uncertainty of design of wind farm
	Not relevant
•	Effect included in monitoring
o	Will be included if situation will be present in the future

Seasonal variability is excluded by sampling only in autumn instead of sampling twice a year for the benthic ecosystem components. To rule out diurnal variability, samples will be collected as much as possible during daytime.

Until 2014, the variation along the nearshore-offshore gradient was focused on two points only (i.e. the Thorntonbank and the Bligh Bank), but this will be expanded in the new sampling design to three points along the gradient. Practically, this implies that it is not necessary to monitor every ecosystem component in each individual wind farm. Most efforts will be done inside Belwind, C-Power and Norther, respectively representing the offshore, midshore and nearshore location.

The aspect distance from a turbine was also added in table 1, as this cannot be entirely excluded from the analysis. It will however be reduced by sampling at two fixed distances from the turbines (i.e. "far" or "close" from/to a turbine). This is also important in the development of the sampling design. This distance will be different for the different ecosystem components, taking the practical restrictions into account of what is technically feasible. It is, for example, technically impossible to measure the effects close to a turbine for epibenthos and demersal fish as it impossible to trawl close to the turbines. The distance aspect or sediment type is not applicable to hard substrate epifauna (i.e. the fouling on the foundations), but here a distinction between intertidal and subtidal is made.

The phase I results of the macrobenthic study showed that the construction phase has a clear impact on the macrobenthic community, but that the impact disappeared during the exploitation phase. This can be due to the fact that there is no impact on the macrobenthos during the exploitation or that the sampling design (few sampling locations with several replicates per location) was not appropriate to detect it. Targeted monitoring however indicated that the macrobenthic community is impacted in the proximity of turbines. Therefore the sampling design will be adjusted in the phase II. From now on a randomized design will be used, which means that more locations inside the wind farms will be sampled but only one sample per location will be collected. The total number of samples will be more or less equal to the phase I monitoring. To determine the effect of the turbines, samples will be collected 'far' (ca. 250m) and 'close' (ca. 50m) to the turbines. Macrobenthic samples will be collected from communities typical for coarse sediments and fine silt sediment (i.e. *Abra alba* and *Ophelia borealis* communities) and possibly also from communities associated with natural gravel beds (at the Norther concession, to be investigated). In practice, samples will therefore be collected at the concession areas of Norther, C-Power and Belwind. It is still to determine which sediment types are present in the Norther concession area, so all options are left open (coarse sand, fine sand and silt, gravel). Combined with type of foundation (GBF, JF and MP) this leads to nine possible combinations. Depending on the seabed survey and the chosen type of foundation, the appropriate options will be selected.

Beam trawl samples to collect the epibenthic fauna and demersal fish species used to be collected in spring and autumn. In the phase II monitoring design this will be reduced to once a year (in autumn), to rule out seasonality. It is not necessary to collect samples in every wind farm along the near-offshore gradient. Considering the knowledge and experience gained from the C-Power and Belwind monitoring, sampling in these wind farms will be preserved. As we know that the Norther concession area holds an entirely different (nearshore) faunal community, it will be necessary to also collect beam trawl samples in that area.

The hyperbenthos (i.e. small sized bottom-dependent animals that live just above the seabed) was not monitored in the past. This was identified as a gap in the data during the workshop. A feasibility study to determine whether or not it is useful to include this ecosystem component in the monitoring programme, will be conducted.

In short, the benthic basic monitoring of phase II will focus on autumn samples to be collected only in three of the (future) eight wind farms, i.e. Norther (nearshore), C-Power (midshore) and Belwind (offshore).

ADJUSTMENTS/IMPROVEMENTS OF THE SAMPLING DESIGN FOR THE BASIC MONITORING PHASE II OF THE PELAGIC REALM

The monitoring of the pelagic ecosystem components will also focus on two to three (depending on the ecosystem component) wind farms along the on-/offshore gradient.

For those ecosystem components it was decided that monitoring will continue until stabilization of the effects occurs. It will continue thereafter for two more years to confirm the stabilization and will then be stopped, if there were at least five years of post-construction monitoring. After a break of five years, the yearly monitoring is restarted for a minimum of three years. Consequently, the seabird surveys in the Belwind wind farm were stopped at the end of April 2015 since we monitored five years post-construction and the effects stabilized. The seabird surveys in Belwind will restart in 2021. The methodology of the monthly seabird surveys as applied in the first phase of the monitoring will however be continued, but the focus will move to the Thorntonbank (C-Power) and the area to the South of the Thorntonbank (Norther concession area). The surveys on the Lodewijckbank (Northwind) are stopped because of the presence of an intermediate community between the nearshore (Norther and C-Power) and the offshore (Belwind) locations. The radar research on the Thorntonbank will be continued year round.

Harbour porpoises are monitored year-round with passive acoustic monitoring devices (C-Pods). Aerial surveys of the entire Belgian part of the North Sea are conducted four times a year. In the future, seals will be tagged with Vemco telemetry tags and GPS/GSM tags; this provided availability of funding.

The (bentho-)pelagic fish community is an ecosystem component which has not yet been investigated within the basic monitoring programme. Whether pelagic fish are attracted to the underwater structures of OWFs therefore remains an open question. It is also expected that the exclusion of fisheries inside the OWFs will have a large effect on the (bentho-)pelagic ecosystem. A preliminary study using a fish-finder sonar (and possibly other techniques) to monitor (bentho-) pelagic fish will be initiated.

Acoustic telemetry tags in cod individuals proved that cod is attracted to the OWFs. The OWFs are of importance especially for younger individuals (one and two years old), showing a high site fidelity. This telemetry study will be continued to study the importance of OWFs also for older individuals.

Bat recorders are installed on the research vessel Belgica, the Belwind platform and a turbine in the C-Power wind farm to study the distribution and density of bats at sea and inside the wind farms. Possibly more detectors will be installed in the future.

Plankton is not being monitored because an impact is unlikely. This might however be different for fish larvae, but this will be the subject of a targeted monitoring action.

Underwater noise measurements are continued inside the operational wind farms and the relationship between wind speed and underwater noise will further be investigated. Measurements during the construction of new wind farms will be conducted.

The sampling location along the nearshore offshore gradient and the timing for the (bentho-)pelagic ecosystem components are summarized in table 3.

Table 3. Sampling location and timing for the (bentho-)pelagic ecosystem components.

ecosystem component	on-offshore gradient			timing
	nearshore	midshore	offshore	
seabirds	•	•		monthly
seabirds radar		•		continuous
marine mammals – C-Pods	•	•	•	continuous
marine mammals – aerial survey	•	•	•	4 times/year
bats		•	•	continuous
(bentho-)pelagic fish – sonar study	•	•	•	monthly
(bentho-)pelagic fish - telemetry	•	•	•	continuous

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