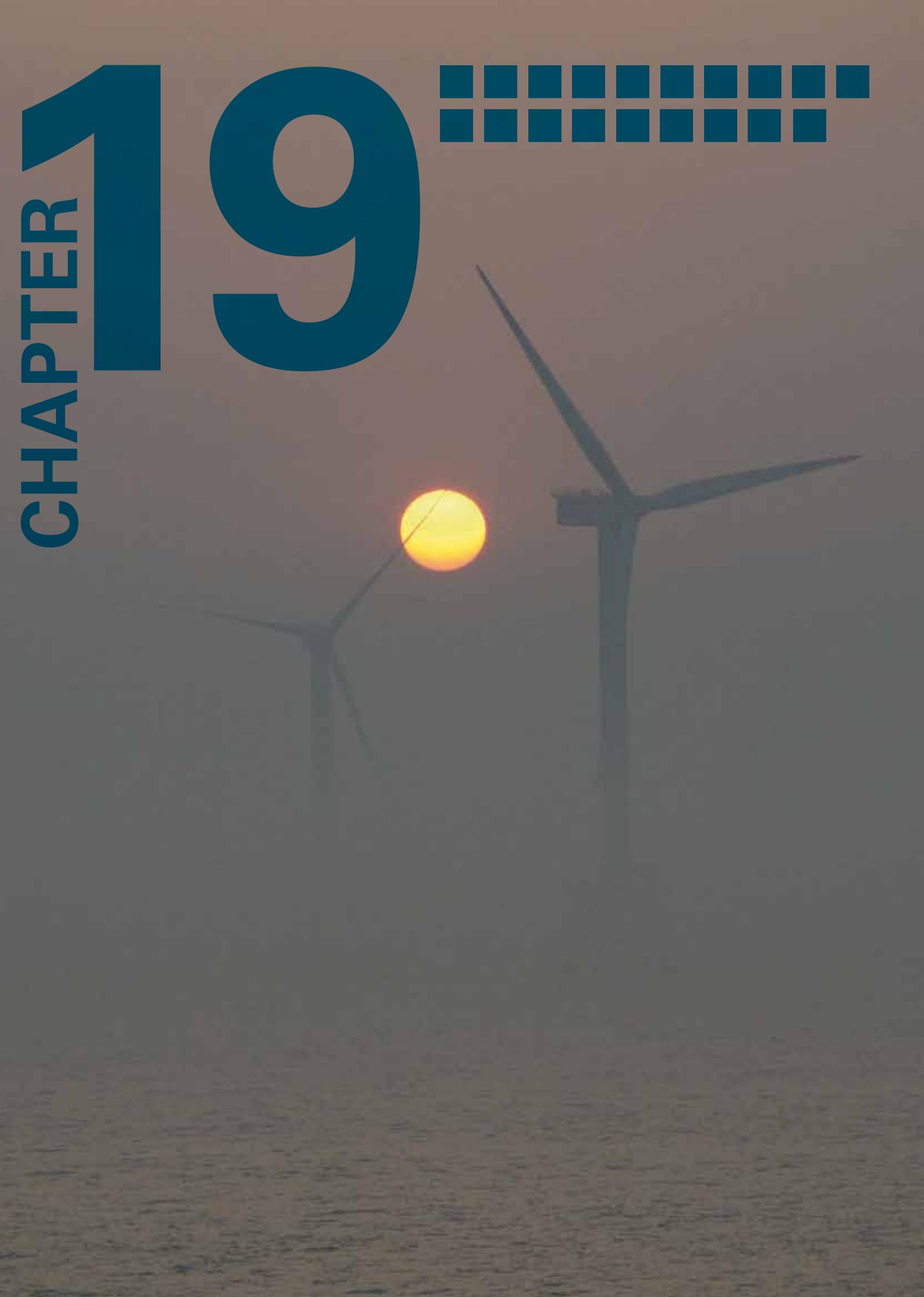
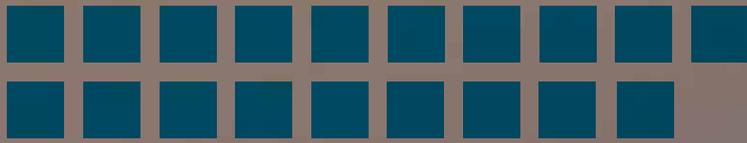


CHAPTER 19



Optimising the future Belgian offshore wind farm monitoring programme

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Six years of monitoring triggered a reflection on how to best continue with the monitoring programme. The basic monitoring has to be rationalised at the level of the likelihood of impact detection, the meaningfulness of impact size and representativeness of the findings. Targeted monitoring should continue to disentangle processes behind the observed impact, for instance the overarching artificial reef effect created by wind farms. The major challenge however remains to achieve a reliable assessment of the cumulative impacts. Continuing consultation and collaboration within the Belgian offshore wind farm monitoring team and with foreign marine scientists and managers will ensure an optimisation of the future monitoring programme.

INTRODUCTION

During the first six years of monitoring, the Belgian offshore wind farm monitoring programme primarily focused on describing the main societal, physical and ecological impacts of offshore wind farms and understanding a selection of processes behind those impacts. Several ecosystem components were investigated and compared with reference conditions at the site and in control areas. This basic monitoring resulted in a comprehensive description of the major changes in the wind farm zone so far (Chapters 3-12). Based on the basic monitoring several hypotheses on the

ecological processes behind the observed impacts were generated and investigated. This targeted monitoring so far focused on a local enrichment in soft sediment macrobenthos near the wind turbines, and the (possible) attraction of fish, seabirds and marine mammals as a consequence of habitat alterations (Chapters 13-16). We further started evaluating the observed impacts and the related ecological processes in a wider context (Chapters 17-18).

Arriving at the end of this first six years of offshore wind farm monitoring, we

reflect on the continuation of the monitoring programme. The main questions to be answered are what programme aspects need correction or continuation, but also what aspects neglected so far deserve scientific attention in the future. This chapter is based on the prospects on monitoring as elaborated in the different chapters and sheds a light on how the future monitoring programme could and should look like to optimally make use of existing knowledge and available resources.

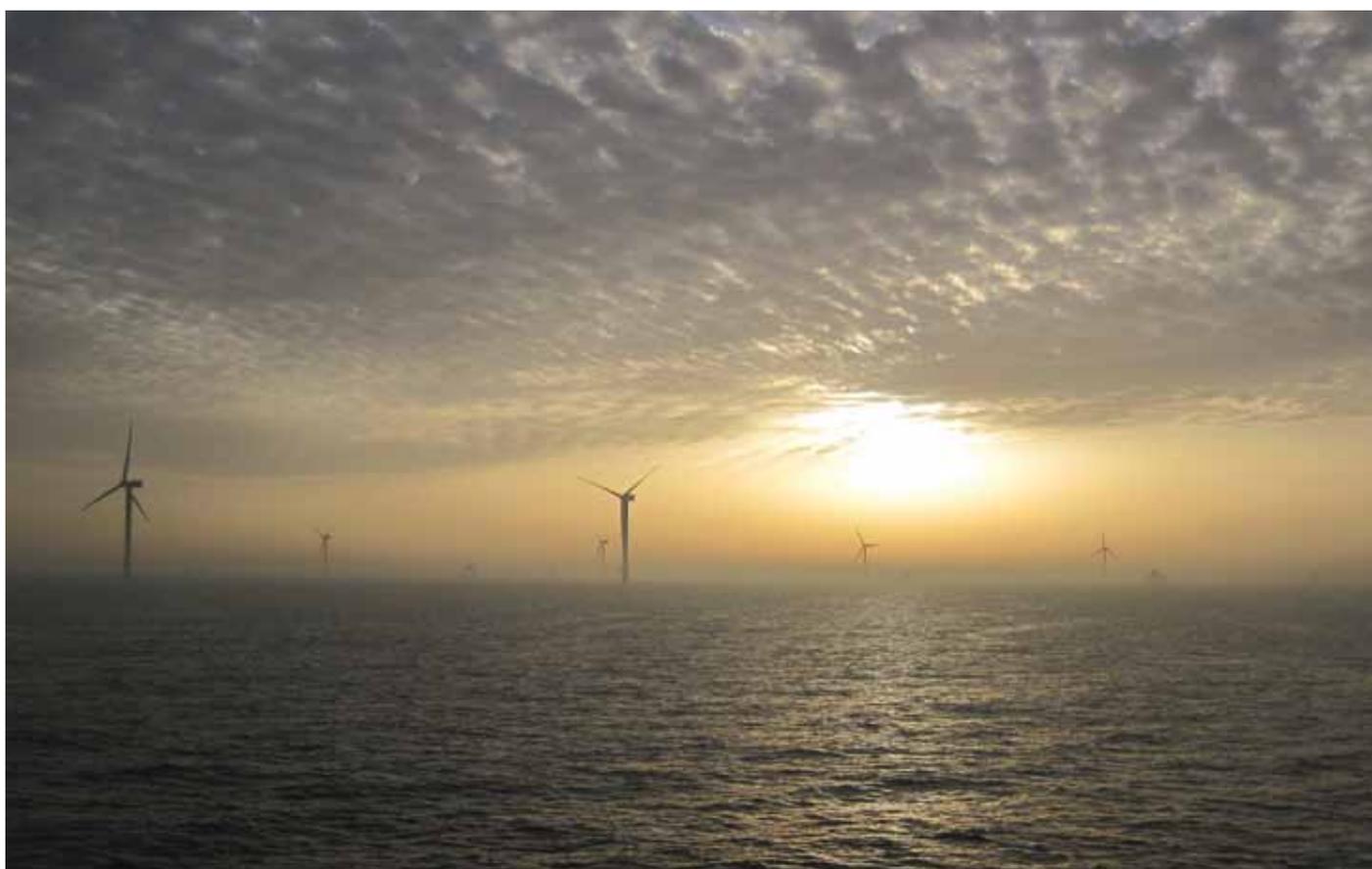
BASIC MONITORING

Basic monitoring focusing on the effect of human activities such as the construction and operation of offshore wind farms is the most common type of monitoring in impact studies. It allows keeping track of major and even unforeseen impacts and is therefore the ideal research strategy to have a finger firmly on the pulse of environmental impact development. It may trigger adjusting or even halting activities in case unacceptable impacts would occur. The continuation of the basic monitoring of all ecosystem components should hence be considered mandatory from a marine ecosystem management perspective, including societal acceptability. The seascape survey for example so far showed the public to generally accept the presence of offshore wind farms. This may however change once the wind farm closest to the coast is constructed, hence requiring future monitoring attention. Some reflections on what has been done so far and how to best continue are however indispensable for an optimisation of the future basic monitoring programme.

In this study, we differentiated between 'positive' and 'negative' responses to offshore wind farms. Next to the impairment of the seascape, ecological 'negative' impacts include the altered sediment characteristics, increased erosion of the natural sandy sediments around wind turbine foundations, an increase in non-indigenous species on the hard substrata, an obvious disturbance of seabirds because of avoidance and collision, and the increased sound pressure on the marine environment and its impact on marine mammals and fish. The 'positive' impacts include the enrichment of the soft and hard substratum invertebrates and fish. So far, all ecosystem components investigated in the Belgian monitoring programme have already shown some degree of response to the offshore wind farms. However, as the ecosystem at the Belgian wind farms is still developing, the patterns observed so

far should be considered short term and hence most probably only reflect the initial stages of the ecological succession. Some impacts may not have been detected yet, simply because they are still not developed to the extent needed to become detectable. The enrichment of the soft sediment macrobenthos observed close to the wind turbines for instance, has been demonstrated to spatially extend through time but is likely not to have reached the spatial extent to be picked up by the basic monitoring of macrobenthos, collecting samples at more than 200 m from the turbines. A continuation of the basic monitoring of all ecosystem components is therefore recommended.

For the future basic monitoring, we should acknowledge the likelihood of impact detection being dependent on research effort, impact size and data noise. Research effort is mainly determined by the amount of observations or samples collected. Impact size is the degree of deviation from the reference conditions and data noise is natural or sampling-induced variability in the data. The low likelihood of impact detection possibly blurring impacts of offshore wind farms on seabirds, has for example been statistically underpinned by the basic monitoring for several seabird species. The current difficulties in demonstrating consistent impacts on the soft-sediment epibenthos and fish throughout the first six years of monitoring is probably related to a combination of natural and sampling-induced variability. This issue certainly needs further consideration when (re)designing the future basic monitoring programme. Here, attention for the statistical power analysis will be needed to quantify the likelihood to detect an impact of a given extent, but equally for methods on how to lower the noise in the data to be explored. For the latter issue, natural variability may be lowered for instance by focusing data collection on one season and as such excluding

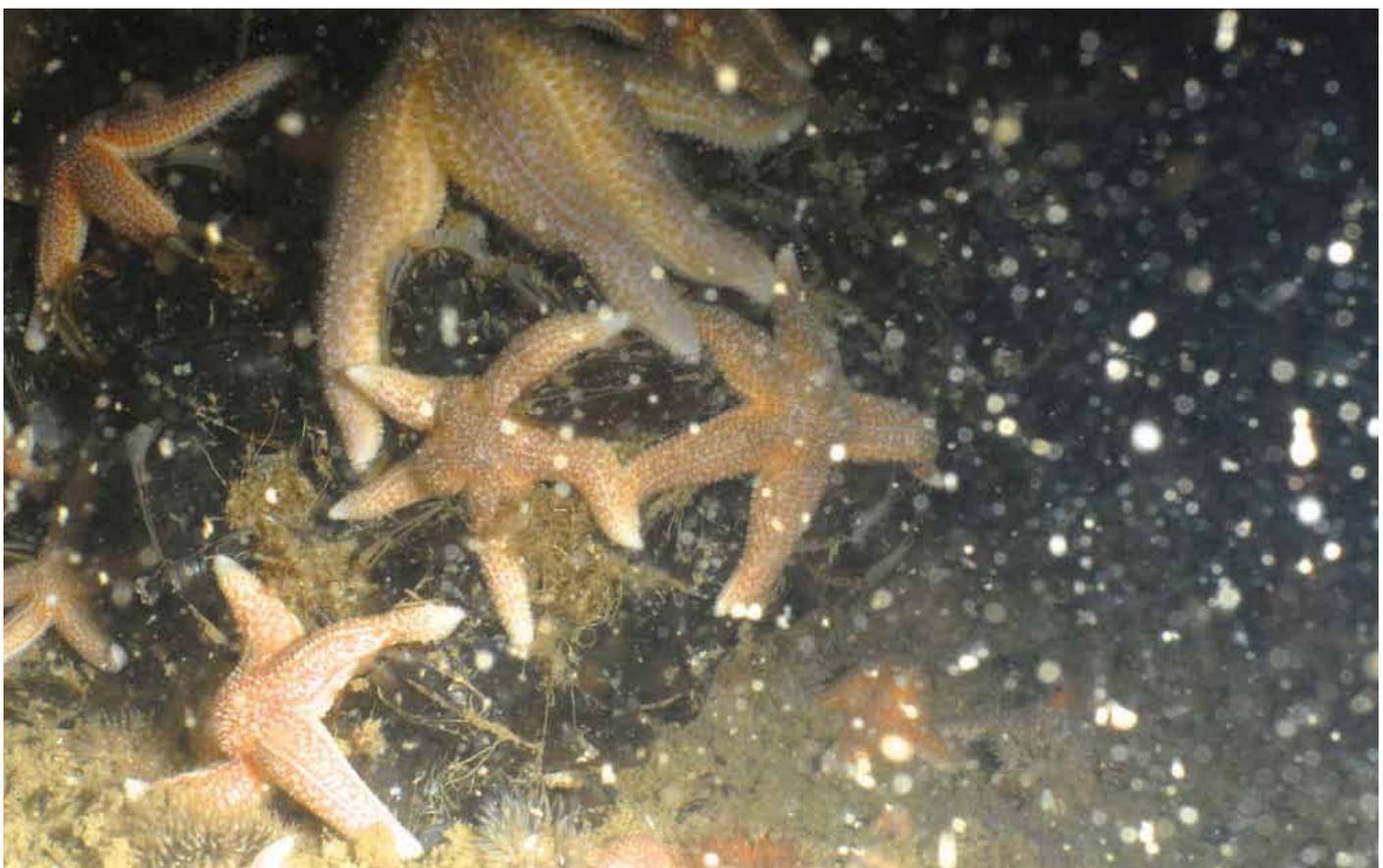


seasonality. Sampling-induced variability in its turn may be lowered by increasing the sample size. A higher number of passive acoustic monitoring devices inside and outside wind farms for example, could facilitate investigating possible harbour porpoise *Phocoena phocoena* attraction to offshore wind farms. Moored equipment (available since mid-2013) will allow recording long time series of underwater noise, during a broad range of weather conditions and various wind farm development stages, and will hence increase the representativeness of underwater noise results. Within a Before-After Control-Impact (BACI) design, an appropriate balance in number of samples per group needs to be targeted. Finally, the relevance of the impact size needs discussion, as we have to accept a certain degree of human-induced impacts on the marine environment, but these impacts should not exceed thresholds of sustainability. Current exercises in the context of the European Habitats- and Birds Directives (Nature 2000), and the Marine Strategy Framework Directive (MSFD) to determine what is acceptable from a nature conservation point of view (Nature 2000: Favourable Conservation Status and Conservation Objectives) or from a sustainability perspective (MSFD: Good Environmental Status and Environmental Targets), will help setting the scene for selecting a meaningful impact limit.

Representativeness of the basic monitoring findings is a major issue to be considered in the future monitoring programme. The research so far mainly focused on two wind farms, which may not be representative for other wind farms by default. Other wind farms are present, are being built or will be constructed, each of these taking a specific position along the onshore-offshore gradient from turbid coastal waters to clear English Channel water, and along the bathymetric gradient from gullies to sandbank tops. These gradients influence the

hydrodynamics and water characteristics, which in turn affect underwater life. Also the occurrence of bird species shows an onshore-offshore gradient. When planning the future basic monitoring, the spatial distribution of the sampling effort along natural environmental gradients will therefore have to be well considered. Additionally, the type of foundations differs between and even within wind farms. Steel monopile and jacket foundations, the latter generally without erosion protection layer, are most common in Belgian waters, while most of the reef effect monitoring, especially concerning fish attraction, has been performed near the concrete gravity based foundations with an extended erosion protection layer. Preliminary comparisons already demonstrated a difference in ecology between the different foundation types. To allow for a solid onshore-offshore comparison and to exclude foundation-related variability, the future monitoring programme should focus on one type of foundation. On the other hand, foundation type-effects should be investigated in a naturally homogeneous environment. Because available resources for monitoring are limited, a well-considered focus and associated sampling effort and allocation is needed.

All of above mentioned considerations, i.e. likelihood of impact detection, acceptable threshold of impact size and representativeness of the monitoring results, will be subject of a workshop on the rationalisation of the Belgian basic offshore wind farm monitoring programme in 2014. This workshop will lead to strategic decisions for a scientifically-sound and feasible basic monitoring programme at the level of research effort and allocation, data noise reduction, and impact size. The fine-tuned programme will come into force from 2015 onwards.



TARGETED MONITORING

Monitoring results that can be used to steer the design of future industrial projects, offer a significant added value to monitoring programmes. For this purpose, a proper understanding of the cause-effects relationships is needed. The targeted monitoring of the Belgian programme aims to understand the ecological processes behind the observed impacts and hence allows extrapolating its results for a better design of future wind farms. Targeted monitoring will continue to be an important aspect of the Belgian offshore wind farm monitoring programme.

The hypothesised cause-effect relationships behind offshore wind farm impacts are plentiful. The Working Group on Marine Benthos and Renewable Energy Developments (WGMBRED) of the International Council for the Exploration of the Sea (ICES) reviewed the cause-effect relationships between offshore renewable energy installations, mainly offshore wind farms, and marine benthos (ICES, 2013)¹. They discovered a wide variety of (possible) causal relationships, all framed in a context of the marine environment as a biogeochemical reactor, as a source of biodiversity and food resources for higher trophic levels. The biogeochemical reactor context alone for example already revealed no less than 17 cause-effect relationships. From their analysis, it becomes obvious that a well-considered selection of priority relationships will be needed to ensure feasible monitoring programmes.

Several cause-effect relationships have already been tackled during the first six years of monitoring. The local enrichment of organic matter in the soft sediment close to wind turbines was found to cause an increase in macrobenthic species richness and density. Some fish and seabird species were found to be attracted to the wind turbines as a consequence of habitat alterations, such as improved feeding conditions. Stomach analysis of cod *Gadus morhua* and pouting *Trisopterus luscus* proved for example that these species primarily predate on the hard substratum epifauna. All chapters on targeted monitoring (Chapter 13-16) present recommendations for future monitoring. For a detailed justification of these recommendations, one is referred to the individual chapters. This section merely aims at highlighting a selected set of hypothesis-driven pathways for further consideration in the future Belgian targeted monitoring programme, taking into account the knowledge obtained during the monitoring so far, ecological and societal relevance, as well as feasibility.

The artificial reef effect will undoubtedly play a key role in the future targeted monitoring. It already received a lot of attention, but various cause-effect relationships remain yet to be tackled. The attraction-production hypothesis in artificial reefs has been investigated in detail for cod and pouting, but several invertebrate (e.g. edible crab *Cancer pagurus* and European lobster *Homarus gammarus*) and fish species common in Belgian offshore wind farms, were so far left unstudied. Investigations of their habitat use for example would shed a light on the key habitat features that are essential to maintain a sustained local population of these species. Also the hard substratum epifaunal community, comprising important prey species for the above mentioned predatory megafauna, needs further targeted attention. Biomass estimates of these prey species may be used to extrapolate food availability to the total footprint of a wind turbine and the whole wind farm artificial reef. Energy and fatty acids profiling of both predators and prey

can open the door to energy transfer estimates and hence elucidate trophic interactions within offshore wind farms. Also the soft sediment macrobenthos in the vicinity of wind turbines may be suitable for this purpose, as the increasing abundance may start playing an important role in the artificial reef food web. The artificial reef effect may further explain the attraction of some bird species (e.g. common tern *Sterna hirundo*) to the wind farms as it is hypothesised that these species benefit from a yet unexplored increased availability of pelagic fish. Whether or not pelagic prey fish also attract marine mammals such as harbour porpoises remains yet to be resolved. Attention to the pelagic fish community in the future monitoring programme is hence of utmost importance. The anticipated positive artificial reef effect may however be partially neutralised by the underwater noise generated during the construction (short term) and exploitation (long term) of offshore wind farms. More hypothesis-driven research on the impact of underwater noise on marine mammals and (the development of) fish is needed to get a full grip on the effect of underwater noise on the marine ecosystem.

While the Belgian targeted monitoring programme anticipates tackling the above mentioned cause-effect relationships, such research should ideally be dealt with in an international setting. The same or at least similar cause-effect relationships are expected in offshore wind farms abroad. This certainly holds true for the southern North Sea, where numerous wind farms are (planned to be) constructed. Given the fact that cause-effect oriented research by definition allows extrapolation outside the area under investigation, there is no need to tackle the same hypotheses in every single wind farm. A well-considered international collaboration as aimed for by initiatives such as WGMBRED, will avoid unneeded repetition of research and would significantly contribute to an optimal use of resources available for wind farm monitoring.



¹ ICES. 2013. Report of the Working Group on Marine Benthos and Renewable Energy Developments (WGMBRED), 19-22 March 2013, Caen, France. ICES CM 2013/SSGEF:17. 23 pp.

CUMULATIVE AND LARGE SCALE IMPACTS

A major challenge for the future Belgian monitoring programme – and by extension all offshore renewable energy environmental monitoring programmes – will be to assess cumulative impacts and to upscale locally observed impacts to the larger scale at which ecological processes take place. The offshore wind farm industry is expanding rapidly and new wind farms are arising fast, not only in Belgium but at several other places in the North Sea and beyond. Current monitoring efforts however mainly focus on the environmental impact of a single wind farm. Because the species that are affected are part of populations extending over larger areas, the focus of the impact investigation should be widened to the population level of those species. For example, for seabirds attracted to the wind farms, there is an increased risk of collision with the wind turbine blades. Whether or not the number of collisions may actually put the sustainability of certain bird populations at risk can however only be reliably assessed when taking account of the multitude of wind farms throughout the range of their populations' spatial distribution. Similarly, the effect on the population of harbour porpoises avoiding areas of pile driving, can also only be assessed in a cumulative offshore wind farm context throughout their distributional range. Furthermore, effects anticipated to be positive from a local perspective, such as the improved feeding condition for cod attracted to the wind turbines, are yet to be evaluated at the population level before final conclusions on the attraction-production hypothesis can be drawn. There is hence an urgent need for scientifically sound thresholds for acceptable overall mortality or habitat loss, which should be investigated at the spatial scale relevant to the population of each species under consideration.

Offshore wind farms are only one of the many human activities in the marine environment. This is yet another aspect relevant to cumulative impact assessment. Assessing the combined effect of all these activities or merely framing the observed impact of wind farms in a broader setting, demands a holistic approach and is of major importance for the future management of the marine ecosystem. While this issue is not new to environmental impact assessment, clear research designs to appropriately tackle the issue are largely lacking. Innovative strategies are needed here.

The monitoring of both types of cumulative effects is very ambitious and cannot satisfactorily be dealt with by a single country or research team. It requires a close collaboration between scientists and administrators, preferably across country borders, to assemble and comprehensively analyse all information that is needed. The complexity is illustrated by the analysis of the fishing effort in the Belgian part of the North Sea, for which realistic distribution maps can only be drafted when VMS data, logbook data and metadata of all Belgian and foreign vessels that operate in the area are compiled, an opportunity that is still missing. The future Belgian monitoring programme will further strive to upscale its findings in a cumulative context, and will search for international collaboration to develop the analytical strategies needed.

