EXECUTIVE SUMMARY

PROGRESSIVE INSIGHTS IN CHANGING SPECIES DISTRIBUTION PATTERNS INFORMING MARINE MANAGEMENT

Steven DEGRAER *, Robin BRABANT, Bob RUMES, Laurence VIGIN, Ulrike BRAECKMAN, Jolien BUYSE, Wouter COURTENS, Annelies DE BACKER, Jan HAELTERS, Kris HOSTENS, Christelle JAMMAR, Nene LEFAIBLE, Tom MOENS, Silvia PAOLETTI, Abril REYNES-CARDONA, Eric STIENEN, Jan VANAVERBEKE, Marc VAN DE WALLE, Nicolas VANERMEN, Tine Miet VAN MAELE & Hilbran VERSTRAETE

* Corresponding author: steven.degraer@naturalsciences.be

At present, eight offshore wind farms are operational in the Belgian part of the North Sea, totalling an installed capacity of 2.26 Gigawatt (GW) and consisting of 399 offshore wind turbines (Chapter 1). They produce an average of 8 TWh annually, accounting for ~1/3 of gross electricity production from renewable energy sources in Belgium. An additional zone for offshore renewable energy, anticipating an installed capacity ranging between 3.15 and 3.5 GW, has been designated in the marine spatial plan 2020-2026. With 523 km² reserved for offshore wind farms in Belgium, 344 km² in the adjacent Dutch Borssele zone and 50 km² in the French Dunkerque zone, cumulative ecological impacts remain a major concern. These anticipated impacts, both positive and negative, are investigated through the WinMon.BE environmental monitoring programme focusing on various aspects of the marine ecosystem components.

Most environmental monitoring programmes for offshore wind farms are halted five years after installation. However, research has shown that this period is way too short and consequently these programmes do not provide the insight needed to manage offshore wind farms in an evidence-based manner. With the Belgian offshore wind farm environmental impact monitoring and research programme, WinMon.BE, we show that fifteen years after the first installation of offshore wind turbines in the Belgian part of the North Sea, progressive wind farm-induced changes in the marine ecosystem are still observed, underlining the importance of long-term research for a sound offshore wind farm management. The WinMon.BE programme has adopted a philosophy of long-term investigation, spanning the full life cycle of offshore wind farms, i.e. from construction to decommissioning. The progressive insights have not only informed the management and development of the first Belgian offshore wind farm zone, which was gradually constructed between 2008 and 2020. Our scientific insights also guided the design of the second Belgian offshore wind farm zone, i.e. the Princess Elisabeth Zone, in an environment-sensitive manner, through the currently ongoing Environmental Impact Assessment procedure.

Long-term impacts of offshore wind farms on the macrobenthic communities inhabiting the surrounding natural soft sediments were investigated over a time span of 13 years (2008–2020; Chapter 2). Our analyses support what is already generally accepted regarding turbine-related impacts. Higher macrobenthos abundance, species richness and diversity are observed in sediments with higher fine particles fractions and total organic matter content. They also confirmed the common pattern of higher abundances in the gullies between sandbanks. Climate-related predictors (sea surface temperature and Atlantic Multi-decadal Oscillation) were significantly correlated with macrobenthic diversity, abundance and species richness. For future studies, it remains important to incorporate local environmental variables that are affected by the turbine presence (like sediment characteristics and organic matter), aside from water depth and climate-related variables. Our study further revealed that no stable state has yet been reached after 13 years of offshore wind farm operations. These findings clearly highlight the importance of long-term studies, as more time is needed (1) for the impacts to get gradually established and (2) to collect sufficient data to be able to detect and observe trends in the response of macrobenthic communities to the presence of offshore wind farms.

Changes in species distribution patterns were identified for demersal fish, as exemplified for plaice *Pleuronectes platessa*, a species extensively studied in terms of its spatial distribution, diet and movement patterns in relation to offshore wind farms (Chapter 3). A combination of visual diving transects (at the turbine scale), beam trawl samples (at the wind farm scale) and acoustic telemetry demonstrated the significance of the scour protection layer and the sandy patches in between the rocks as a feeding habitat for plaice. Plaice benefits from the increased food availability at the hard substrates, as indicated by a trophic analysis combining gut content analysis with a biomarker approach (fatty acid analysis). Despite the increased prey availability, morphometric (i.e., Fulton's K index) and organosomatic condition indices (i.e. fullness-, gonadosomatic-, hepatosomatic and digestive-somatic index) did not (yet) reveal evidence of a better condition in plaice, potentially due to the sampling size being too small to detect differences. Our findings suggest that offshore wind farms serve as a refuge for plaice, potentially mitigating direct fishing mortality and likely enhancing plaice production. It remains to be investigated whether this translates to spillover effects into the adjacent areas where fishing is permitted and how such effects may affect fisheries, given the anticipated large-scale expansion of offshore renewable energy zones in the broader North Sea.

Altered species distribution patterns in relation to the presence of offshore wind farms are not independent of other human activities, such as shipping, fisheries and mariculture. This is particularly the case for highly mobile species like marine mammals. We used aerial survey data collected between 2009 and 2022, and analysed the spatio-temporal distribution patterns of the harbour porpoise *Phocoena phocoena* in function of selected environmental drivers and anthropogenic stressors (Chapter 4). The distribution of harbour porpoise followed a consistent seasonal pattern, with the highest densities in spring, but with high interannual variability, with abundance peaks in 2011, 2014 and 2018. Harbour porpoise distribution correlated with latitude and longitude, with the species preferring the western part of the Belgian part of the North Sea, revealing a strong overlap with the Vlaamse Banken Special Area of Conservation (SAC). The distribution was also significantly negatively correlated with marine traffic intensity and distance to the closest offshore wind farm. However, it is essential to exercise caution to avoid overinterpreting these correlations. Further monitoring and research is recommended to better understand the interaction between natural factors, such as prey availability, and anthropogenic stressors, driving the spatial distribution of harbour porpoises.

With an ever increasing number of offshore wind farms in Belgian waters, monitoring programmes need to be adaptive to ensure gaining the best knowledge on changing species distribution patterns. The adapted monitoring strategy for seabirds not only aims to detect displacement responses, it is also designed to detect avoidance distances and the effect of turbine density on seabird displacement (Chapter 5). The results presented at this stage (count data from February 2021 to April 2023) need to be considered as indicative since more data and advanced spatial modelling are needed to detect potential seabird avoidance or attraction effects with sufficient confidence. Nevertheless, based on this limited dataset and mean values, it is interesting to see that for several species, the observed responses are in line with what has been found before and/or elsewhere. As such, our results indicate an attraction effect for great black-backed gull *Larus marinus* and great cormorant *Phalacrocorax carbo*, and an avoidance effect for northern gannet *Morus bassanus*. On the other hand, we no longer noticed a (strong) avoidance of common guillemots *Uria aalge* and even observed an increased number of razorbills *Alca torda* in the wind farms, possibly indicating habituation or specific habitat preferences. The revised monitoring design aims at informing future planning decisions regarding wind farm configuration to mitigate the impact on seabirds.

Aside a bird-sensitive wind farm design, mitigating the impacts on birds may also entail measures to reduce bird collision numbers. The southern North Sea is one of the main migration flyways in Europe. The highest flight intensities at sea are recorded at night during spring and autumn migration, mainly of migrating passerines, which normally migrate at high altitudes, up to several kilometres. However, a portion of these songbirds flies at rotor height of the wind turbines and are thus at risk of collision. Temporarily stopping the turbine operation during high collision risk events for songbirds, e.g. when adverse weather conditions bring large numbers of passerines into the range of the turbine rotors, may substantially prevent collision mortality. However, this management measure has not yet been applied regularly (Chapter 6). The Netherlands are pioneering curtailment measures in offshore wind farms and, Germany and France are starting to perform tests, while other countries are open for discussions on the topic. Temporarily turbine shutdowns may be highly effective for reducing collision mortalities in certain scenarios, but site-specific monitoring programmes remain necessary to assess the effectiveness and the finetuning of the measure. Furthermore, a regional approach may be most appropriate to maximize the efficiency and ecological benefits of such measure.

In conclusion, the results presented in the present WinMon.BE monitoring and research report demonstrate the importance to progress our insights in changing species distribution patterns in relation to offshore wind farms. Fifteen years past the installation of the first turbines in Belgian waters, the marine ecosystem has not yet reached a new equilibrium, as demonstrated for the soft sediment macrobenthos communities inhabiting the sandy sediments surrounding the turbines and scour protection layers. Continued, new and detailed research is indispensable to further our understanding on how marine ecosystems respond to wind farms. This research should not only focus on the attraction of hard substrate species, but also on species that are less evidently impacted by offshore wind farms, such as plaice and other demersal (flat)fish. We need to critically reflect on the efficiency and effectiveness of our and other regional monitoring and research programmes to ensure collecting the best data, as shown with the re-designed monitoring programme for seabirds. As demonstrated for marine mammals, we need to address the most pertinent questions, e.g. the contextualization of offshore wind farm effects. Progressive insights are necessary to feed evidence-based, efficient and effective mitigation measures – such as regional curtailment programmes - and to develop and design eco-friendly offshore wind farms.