# Summary

FaCE-IT (Functional biodiversity in a Changing sedimentary Environment: Implications for biogeochemistry and food webs in a managerial setting) aimed at investigating the effect of multiple wind farms on a large geographical scale. Such knowledge is increasingly needed as the number of offshore wind farms is rising, while knowledge on the effect of these installations is generally limited to knowledge gained from monitoring programmes. These monitoring programmes are often designed to assess local structural changes in the environment, and generally only last a limited amount of time after installation of turbines. However, sustainable use of the marine environment requires a clear understanding of the functional effects of multiple activities at larger geographical scale.

FaCE-It was based on a combination of detailed measurements in the vicinity of a turbine and at a larger scale along a sedimentological gradient. These data, combined with dedicated experiments yielded the necessary data on carbon and nitrogen dynamics for a geographical upscaling using a newly built oceanographic model.

The detailed observations around a turbine showed that the structural differences in communities were functionally reflected as different compartments of the food web associated with offshore wind turbines. The lowest food-web complexity was found in areas dominated by suspension-feeding organisms (the intertidal zone, and the Mytilus zone below this intertidal zone), whereas highest complexity was observed in zones where organic matter accumulates. In this respect, the scour protection layer was the artificial zone with the highest food-web complexity zone. The current design of scour protection layers not offers a shelter and increased amounts of food, but also a higher diversity of food items. As such, an ecological friendly designed scour protection layers might act as nature restoration tools.

Furthermore, our detailed observations showed that the pelagic fish species horse mackerel uses the offshore wind farms opportunistically as feeding grounds. More importantly, we confirmed the earlier findings that two benthopelagic fish species (pouting and juvenile cod) use the windfarms as feeding area for a longer period of time, and we added the benthic species sculpin as an additional species using the offshore wind habitat as foraging area for a longer period of time. As such, restriction of fishing activities within offshore wind farm areas allows certain species to remain in the area without being caught while having the opportunity to benefit from available feeding grounds, which can lead to a local increased fish production.

As a first upscaling exercise, we performed a pulse-chase experiment to estimate the effect of large densities of suspension feeders in localised patches in offshore wind farms. Our estimates show that the dominant organisms (the amphipod *Jassa herdmani* and the blue mussel *Mytilus edulis*) on all turbines in the Belgian part of the North Sea ingest 657 ton organic carbon per year, which corresponds to 1.3% of the annual primary production in the Belgian OWFs. While the effect on the pelagic realm can be considered small, further FaCE-It work (see below) showed that this has important consequences for the benthic ecosystem.

In order to increase our understanding of benthic ecosystem functioning, we performed detailed lab incubations to quantify biogeochemical cycling rates and link these to the combination of physical and biological properties of the sediment. This was done in close vicinity of the same

turbine that served the food-web research, and along a gradient from fine to coarse sediments to facilitate later upscaling efforts. In order to run these experiment, we developed a new method for continuous measurements of bioirrigation, and introduced permeability (here: the capacity of a fluid to flow through a sediment) as a key environmental variable in Belgian biogeochemical research. For the first time, we showed the importance of Dissimilatory Nitrate Reduction to Ammonium (DNRA) in the benthic nitrogen cycle in the Belgian part of the North Sea, notably in well irrigated sediments with low organic matter content, where nitrogen is not removed from the sediment but returned to the water column as biologically available ammonium. Permeability was a key variable to explain the biogeochemical processes and should be incorporated as standard environmental variable in biogeochemical studies.

Building on the biogeochemical study and additional datasets, we explored the use of functional indices to be used to cover the ecosystem functioning component in ecosystem health assessments for the Marine Strategy Framework Directive and the Habitat Directive. We explored three families of functional indices: a first one is based on the trait modalities involved in actual behaviour of organisms inhabiting a sea floor, resulting in particle displacement and bioirrigation (solute exchange across the sediment-water interface), covered by the Bioturbation Potential of the community (BPc) index and the Bioirrigation Potential of the community index (IPc) respectively. Our results suggest that currently BPc is a suitable index to reflect biogeochemical functioning in the relevant habitats, whereas IPc needs some finetuning to be used as indicator for EU Directive assessments. A second family of functional biodiversity indices reflect properties of the entire functional space occupied by a community. Our results suggest that two indices (Functional Richness [FRic] and Functional eveness [Feve] can be considered as promising tools, provided that threshold values for good status are set. Finally, we investigated the use of Sediment Profile Imaging (SPI) derived indices, and concluded that the Benthic Habitat Quality index can be a useful tool to use for assessments in the Belgian part of the North Sea, albeit after some implemented modifications.

The spatial upscaling, investigating the effect of multiple wind farms at a larger geographical scale was made possible by dedicated model development and integration of the detailed measurements and experimental results in this newly developed model. Whereas the effect of the presence of OWFs on the pelagic realm is limited, the opposite was found for the sea floor. The models showed that there is an increase in deposition of organic matter within (up to 50%) withing the OWF, and between 2 and 15% in the immediate vicinity (2km) of the wind farms, which can affect the benthos. Further away, the deposition of organic carbon decreases. This decrease is smaller than the local increase within the OWF, but stretches over much larger areas. As such, it is clear that effects of offshore wind farms are transboundary: the planned French OWF will affect the Begian part of the North Sea, the effect of the Belgian OWF extends into the Dutch waters. The local increase in deposition of organic matter triggers changes in the benthic mineralisation pathways. Generally, mineralisation rates increase, through a strong increase in anoxic mineralisation rates and to a lesser extent as a consequence of increasing oxic mineralisation. This results in accumulation of organic matter within OWF areas. During the life span of the OWFs, the upper 10 cm of the sediments in the current wind farms can store 28700 tonnes of carbon, which increases to 48400 tonnes when new OWFs are installed in the new concession area. This coincides with 0.014 to 0.025% of the total annual Belgian $CO_2$ emissions. The carbon storage in Belgian OWF sediments thus contributes with a small but significant reduction in CO2 emissions.

The model allows to help defining the locations of the new OWFs in Belgian waters as well. The new concession zone coincides with the marine protected area of the Vlaamse Banken, where valuable gravel beds are protected under the Habitat Directive. The model shows that negative effects on these vulnerable gravel beds can be avoided by location the turbines either at least 3 or 7 km away from the gravel beds in the downstream or upstream residual current direction respectively, or 2-4 km away from the gravel beds in the direction orthogonal to the residual current.

Apart from its **scientific output** (3 PhD's, 13 peer reviewed papers, 25 posters and presentations on scientific conferences), FaCE-It provided added value in many aspects. The tightly coordinated research resulted in a strong Belgian 'OWF research community', from which at least 4 currently funded projects have rooted. FaCE-It created **new methodology and tools**, made available to the Belgian and international research community and has contributed to the training of **the future generation of marine scientists** through two summer schools and annual field training of MSc students. FaCE-It scientists have actively supported policy in Belgium and abroad, amongst others through recommendations for OWF installations and sharing knowledge and expertise on ecological framework of offshore wind developments. Active interaction with stakeholders in the project resulted in increased scientific output, with testable scenarios for the integrated final FaCE-It model on the effect of OWFs on the carbon dynamics in the marine ecosystem.