BE WILD

Biodiversity Enhanced Wind Farm development, Integrated monitoring & inspection and Localized Design

A MOOI project progress report year 1

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Mecal Advanced Tower Systems
CrossWind

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1 Summary

Background

In the coming years, many new wind farms are to be built in the North Sea. In 2030, these wind farms are projected to provide21.5 GW, which is 40 percent of the current electricity consumption in the Netherlands. Wind farms both offer opportunities and pose risks for nature. There are for example risks for birds and bats, while construction work causes temporary disruption to marine mammals and could potentially affect marine life on the seafloor (in particular cable laying activities). Opportunities arise especially underwater. In wind farms it is not allowed to carry out seabed disturbing activities such as trawl fishing. By installing artificial structures that are integrated in existing offshore wind structures, it is possible to accelerate and strengthen the development of biodiversity within wind farms.

Impact on sea life in the area of wind farms is not yet fully understood (negative and positive effects), while performing in-depth ecology research on-site is expensive due to the logistics. Yet, there are little incentives for offshore wind farm operators to invest in ecological optimizations when the benefits are not clear and the risk of failures for chosen biodiversity interventions are high. Moreover, investments in offshore wind farms are already very costly, and as a consequence investors want to reduce external risks as much as possible. Potential other users of the same wind farm location, such as shipping, fishery and nature, are therefore not much welcomed in the same area as they could potentially harm the operational reliability of the wind farm. An integral understanding is needed in order to accelerate the roll out of offshore wind in the North Sea in a (ecologically) sustainable manner.

Purpose of the project

Without measures, the wind farm operators are limiting other functions that could be performed in the area, while the environmental footprint of O&M tasks in wind farms is relatively high. By implementing an integral approach on data collection and analyses for wind farm operations and ecology, the operational costs can be reduced while valuable datasets can be delivered, with positive outcomes for the wind sector and nature. Furthermore, the deployment of robotic systems such as Unmanned Surface Vessels (USVs) and underwater Remotely Operating Vehicles (ROVs) hold the potential to substantially reduce operational costs for wind farm inspection and maintenance compared to common practise of using (large) support vessels with staff in the wind farm.

The objective of the project is to develop synergies between ecological and technological needs, activities and requirements in order to effectively tackle key challenges in **realizing an economically and ecologically sustainable expansion of offshore wind energy** in the North Sea towards 72 GW in 2050, thereby reducing societal costs.

In order to reach such synergies, it is crucial to integrate **new measuring and sensor systems (such as eDNA sampling)** and to ensure optimal data collection and analyses methods, preferably onboard of robotic systems such as USVs and ROVs. This requires advancements in the measurement systems and improved robotization techniques that allow for **more autonomous operations** (remotely controlled) with smaller vehicles, which makes deployment of multiple units commercially feasible and therefore expanding the measurement capabilities (more measurements in less time). This contributes to speeding up the phase of site preparation of offshore wind farms, while **enlarging the data collection capacity** during the operational stages of wind farms. In combination with new advancements in underwater robotics (ROV's), it will be possible to collect data closer to the existing structures than currently possible. Lastly, the implementation of **Biodiversity Enhanced Scour Protection** measures that can be delivered on the scale, price and quality required for offshore windfarms, fully adaptable to local conditions, will speed up ecological developments in wind farms.

Results

At the end of the project, the following results will have been achieved:

- Monitoring with e-DNA samples: this is a cost-efficient and non-invasive method to identify which species are present at a particular location in the wind farm. It does not require a detailed look with camera's subsea and/or interacting with living organisms, making it a low-cost and scalable solution.
- Cable detection sensor: having an integrated, highly accurate cable detection sensor onboard on an USV-ROV allows for making more frequent cable inspection surveys and, in case of a failure, to pinpoint the location of the cable fraction much faster.
- Biodiversity enhancing scour protection based a modular and industrialized design that can be modified in such a way that in addition to its primary protective function, it can enhance ecological functioning against low additional costs compared to existing scour protection measures.
- Integrated USV solutions. Having the latest sensing and analyses capabilities integrated on an unmanned vessel allows to do more measurements all at the same time, creating a complete view of the status of both the subsea structures and subsea life. The integrated IRM solution allows for more frequent data collection of all different variables at the same time, enabling the offshore wind farm operators to make well-informed decisions on possible interventions that are needed. This lowers the risk on possible technical or ecological failures subsea.

Actual status

At the end of our first year, the project is running on time and budget. Work has been commenced by teams at Fugro to develop the test eDNA sampling and computer vision technology to be deployed on our eROV. Both PhD students (marine ecology and marine policy) have been recruited at Wageningen University and commenced their research as planned. Seekable has made significant progress in the development of their cable tracking sensor. Mecal have conducted engineering research, scoped their design, and settled on an approach to be detailed and tested in 2024. In conclusion, we have delivered our milestones for 2023 and are on track to meet our milestone commitment for 2024.

2 Description of executed activities

Project activities follow the following structure:

1. Design of an integrated full area measurement and analysis strategy
2. Development of novel USV/ROV monitoring equipment (new sensor developments)
3. Integration of new devices with the Fugro USV/ROV combination
4. Selection and design of biodiversity enhancement options
5. Validation and market preparation of the integrated USV-ROV monitoring and inspection solutions
6. Research into new and improved policy strategies

The project is currently running for 1 year. The following activities are planned to reach the above results:

1.1 Result 1 Design of an integrated full area measurement and analysis strategy

Result	Activities	Progress after year 1
1.1 Design of an ecological measurement strategy	Performed literature study and had discussions with Eneco regarding sampling campaigns.	Decided on sampling campaign, collecting eDNA in CrossWind every three months, over the course of three years.
1.2 Design of an overall wind farm inspection and measurement strategy	Developed and agreed methodology between partners.	Complete and output Survey Strategy.
1.3 Development of improved eDNA analysis methods	Conducted test experiment for native sequencing using water from oyster tide pools on which different target enrichment treatments were tested.	Conducted test experiment and part of the data analysis. Will decide on filter type to use in CrossWind sampling campaign prior to sampling.
1.4 Research and development regarding possibilities for remote eDNA analysis on board the USV	Discussion between WUR-MAE and Fugro on the sampling device.	Came up with novel sampling device, which can be attached to ROV.

1.2 Result 2: Development of novel USV/ROV monitoring equipment

Result	Activities	Progress after year 1
2.1 Design and prototyping of a novel submarine cable tracking methodology	The cable tracker system comprises a range of submerged sensors and a top unit housing the computing device. These sensors are sourced from selected	We have successfully conducted comprehensive tests on our cable tracker in various scenarios, providing valuable insights into its performance. Testing phases included, land,

	manufacturers, eliminating the necessity for custom sensor development.	sensor setup, accuracy, sensitivity, onshore cable, and offshore cable landfall. In summary, our cable tracker has shown promising results in detecting and estimating positions of various cables. However, ongoing research and refinement of the algorithm are essential to enhance performance in specific scenarios, ensuring reliable cable tracking capabilities both onshore and offshore.
	Engineers from Fugro, involved in the USV-ROV development, have engaged in several meetings with the Seekable development team. The focus of these discussions was the formulation of a strategy for integrating the cable tracker system with the USV-ROV. Notably, the USV-ROV was designed with the capability to connect to generic sensors, aligning with the cable tracker's utilization of a business-standard interface prevalent in the offshore industry.	The design of how the ROV is parked inside the USV adds a constraint to the cable tracker sensor frame setup under evaluation. While the general procedure for connecting the cable tracker to the USV-ROV is straightforward, additional specific testing is deemed necessary. Concurrently, plans for connecting the cable tracker to Fugro's ROV have been initiated, with the inaugural tests scheduled for the first quarter of 2024.

1.2.1 Seekable Cable Tracker Testing Phases

1. **Land Testing Scenarios:**
    - Single conductor cables were arranged in a square formation for testing on land.
    - The cable tracker was subjected to different aspects, allowing us to assess its behavior under various conditions.
2. **Sensor Setup Testing:**
    - Vertical and horizontal sensor setups were tested to evaluate their impact on the cable tracker's performance. Tests for asymmetric sensor setups were prepared, including theoretical evaluation of potential performance.
    - The effects of signal frequency and strength in the cable were analyzed to understand their impact on estimation accuracy.

- Proximity of other cables, sensor noise, and a tilted sensor were considered in the testing scenarios.

3. **Estimation Accuracy:**
    - The system demonstrated the capability to detect cables and measure positions with an accuracy ranging from 5 to 90cm within a distance of 0 to 10m on land cables.
4. **Sensitivity to Recording Setup:**
    - The cable tracker's sensitivity to the recording setup was highlighted, emphasizing the need for careful assembly.
    - Misaligned sensors and static errors in position and orientation were identified as potential sources of significant errors, especially at greater distances.
5. **Testing on Onshore Wind Farm Inter-Array Cable:**
    - Successfully tested on a three-phase non-twisted cable, prompting the need for an update in the estimation algorithm.
    - Additional research is required to optimize the algorithm specifically for this cable type
    - Theoretical and experimental research has shown that onshore inter-array cables differ significantly from offshore inter-array cables in the way they can be detected.
6. **Testing on Offshore Windpark Export Cable:**
    - Conducted tests at the beach landing point on a twisted three-phase cable commonly found in offshore windparks as export and inter-array cables.
    - Accurate detection and position estimation within 5 to 90cm at a distance of 0 to 10m were achieved.
    - Identified specific artifacts when measuring this cable type, especially above the cable, indicating the need for algorithm adjustments.

Result	Activities	Progress after year 1
2.2 Design and prototyping of an offshore USV eDNA water sampler and filtration device	Multiple workshops have been undertaken between Fugro and WUR to determine requirements. A market analysis has been undertaken by Fugro to understand if suitable products are available.	It was decided that a USV mounted auto-sampler would not be the most suitable solution because it would require a long hose, adding complexity and increasing risk of contaminating samples. A similar auto-sampler is available on the market and has been procured by Fugro separately. Findings from that pilot will be compared in this project.
2.3 Design and prototyping of a subsea water sampler to be fitted onto an ROV		Concept designs for an ROV specific eDNA sampler have been developed and iterative development commenced. In parallel, two auto-samplers have been procured by Fugro's operational divisions and performance will be compared

		as part of the development process.
2.4 Design and prototyping of sensor systems for environmental monitoring and other core USV equipment	Requirements have been defined, assessment of available software on the market, and assessment of USV/eROV operations undertaken.	A computer vision team has been established at Fugro to explore this topic. A scope for a Proof of Concept has been developed, challenges identified, and the process of data acquisition has been determined. Initial trials alongside Fugro USV trials will be undertaken mid-January 2024.

1.3 Result 3 Integration of devices with the Fugro USV/ROV combination

This table refers to the collaboration between Seekable and Fugro. Development of autosamplers and computer vision technology by Fugro is conducted in collaboration with USV-ROV teams as standard.

<table>
<tr><th>Result</th><th>Activities</th><th>Progress after year 1</th></tr>
<tr><td>3.1 Design and prototyping of required technical modifications to the ROV for effective deployment of new measuring devices</td><td>Engineers from Fugro, involved in the USV-ROV development, have engaged in several meetings with the Seekable development team. The focus of these discussions was the formulation of a strategy for integrating the cable tracker system with the USV-ROV.</td><td rowspan="3">The design of how the ROV is parked inside the USV adds a constraint to the cable tracker sensor frame setup under evaluation. While the general procedure for connecting the cable tracker to the USV-ROV is straightforward, additional specific testing is deemed necessary. Concurrently, plans for connecting the cable tracker to Fugro's ROV have been initiated, with the inaugural tests scheduled for the first quarter of 2024.

Fugro will determine if the needed modifications to the ROV would be too expensive to add value to OW customers and will complete a Go/No Go decision in 2024 on whether to proceed to ROV sea trials from the USV-ROV. Alternatives may be possible from ROVs deployed from crewed vessels.</td></tr>
<tr><td>3.2 Design and prototyping of required technical modifications to the USV for effective deployment of new measuring devices</td><td>Discussions started between design team and ROV team. However, it is anticipated that the Seekabe sensor is more likely to be fitted to the ROV than the USV.</td></tr>
<tr><td>3.3 Development of enhanced control systems to enlarge autonomy of the system</td><td>Notably, the USV-ROV was designed with the capability to connect to generic sensors, aligning with the cable tracker's utilization of a business-standard interface prevalent in the offshore industry.</td></tr>
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1.4 Result 4 Selection and design of biodiversity enhancement options

Result	Activities	Progress after year 1
4.1 Design and prototyping of biodiversity enhancing and functionally sound elements for scour protection	Performed a background study and a design study. Performed a study about material mixtures that promote flat oyster settlement and other marine species are preparing for a physical test to validate. Preparing for the laboratory (flume) test to validate the elements' stability.	We have several scour protection concepts and one detailed design of a scour protection element. We have a material selection to be used for the elements.
4.2 Validation of the new scour protection, including installation thereof, in a realistic environment	Started the collaboration with CrossWind for the field test plan.	We have several options for a field test. All options would take place in 2025/2026.
4.3 Supply chain and logistical analysis	Executed a preliminary analysis. Detailed analysis is planned for 2024.	Study results about limitations and costs, which was used as design input.
4.4 Research into additional applications of development biodiversity enhancing structures	Performed a background study.	We have a benchmark study and an impression of which directions to go.

1.5 Result 5 Validation and market preparation of the integrated USV-ROV monitoring and inspection solutions

Result	Activities	Progress after year 1
5.1 Development and planning of testing campaigns to validate the developed integrated monitoring inspection strategy	Starts in H2 2024	Although this Result starts in H2 2024 on the program, test schedules for the different aspects have been drafted and commenced as part of product development.
5.2 Performing testing campaigns and analysis and reporting of results	Starts in H2 2024	
5.3 Supporting actions toward market introduction	Starts in H2 2024	

1.6 Result 6 Research into new and improved policy strategies

Result	Activities	Progress after year 1
6.1 Review current and upcoming policies regarding biodiversity in the offshore wind sector.	Reviewed literature and policies regarding the monitoring and management of biodiversity in the North Sea. Attended relevant policy conferences: i.e. Noordzeedagen, which provided networking opportunities with Dutch policymakers, especially on biodiversity enhancement in the North Sea.	Gained insights into the policy challenges and opportunities for the implementation of eDNA water sampling as a monitoring tool for biodiversity. Insights will form basis of research output in 2024.
6.2 Identify opportunities for governing automated biodiversity data by variety a range of offshore wind energy related actors	Initial research conducted on current stakeholder involvement, with intentions to explore data access, use and/or sharing opportunities.	Research proposal and framework for empirical data collection completed for implementation in 2024.
6.3 Research into strategies to stimulate biodiversity enhancing activities	Initial research conducted surrounding decommissioning debates as a form of stimulating biodiversity enhancing activities.	Research proposal and framework for empirical data collection completed for implementation in 2024.
6.4 Establishing and sharing of recommendations to relevant stakeholders	Starts Q2 2025	

3 Description of contribution towards MOOI regulation

The project is part of MOOI innovation theme A-1 as included in the thematic description of the MOOI subsidy scheme (link), i.e. 'electricity, innovations as integral part of offshore wind energy farms'. Within this theme the following of the mentioned 'research and development topics' are addressed:

R&D topics Mission A, theme 1	**Contribution of the BE WILD project**
Increasing the safety and reliability of wind farms and decreasing the costs of exploitation through robotisation of monitoring and maintenance, using innovations within the fields of diagnostics, sensors, communications systems, AI and control systems (bullet 1 of the MOOI R&D theme description).	The consortium will develop new sensors and analysis software to perform better inspection, monitoring and maintenance tasks in offshore wind farms. In addition, the robot systems that Fugro uses in its IRM services (USVs and ROVs) will be significantly upgraded in order to accommodate the new sensors and will have better processing, positioning and station keeping functions that allow for more reliable and complete surveys in offshore wind farms. Such advanced robotisation allows that more functions can be performed by unmanned systems which leads to significant cost reduction for wind farm operators (see section 3.2.1).
R&D topics Mission A, theme 1	**Contribution of the BE WILD project**
Modular, circular and integral design methods and standardization of components in order to reduce costs and (raw) material usage (bullet 4 of the MOOI R&D theme description);	The project entails an integrated technological and ecological sensing system onboard of one robotic system (USV-ROV), which will be modular in design and components (sensor units and collected samples) can be exchanged/transferred depending on the exact inspection mission needs. Moreover, the projects includes the development of a modular industrialized scour protection system that fosters subsea biodiversity in wind farms. This will be the first time that such biodiversity enhancing scour protection will be implemented on large scale (for an entire turbine) with the perspective to standardize (industrialize) this for upscaling to entire wind farms.
Optimalization of wind farm management strategies with the aim of optimally embedding the renewable energy production and reducing operational and maintenance costs (bullet 5 of the MOOI R&D theme description);	The Operations & Maintenance (O&M) strategy for offshore wind farms can be optimized based on insights derived from the complete datasets that are collected from the integrated technological and ecological sensing systems onboard of the USV-ROV combination. For example, after monitoring seabed changes over a period of 5 years, it could appear that on particular locations in the wind farm there is very little change, while in other locations there is lot of dynamics (e.g. new depositions of sand, washing away of rocks, etc.). The O&M strategy can then be optimized by having only more frequent inspections in the dynamic sites, which will save on O&M costs.
Innovations in the field of design, installation and exploitation of wind farms that have a positive	This subject is very close to the overall objective of the project, as we aim for including the monitoring of the ecological situations by eDNA techniques when performing the regular

net impact on habitats and ecology (below and above water) by means of mitigations and compensation of potential negative effects and by means of strengthening of natural systems (bullet 8 of the MOOI R&D theme description).	technical inspections in wind farms. In this way, wind park owners/operators generate additional insights 'in one go' about the impacts on subsea habitats and ecology without extra costs. In addition, the project will introduce cost-efficient (because industrialized) scour protection measures that are aimed at promoting new habitats for underwater species. This will not only compensate for possible negative effects of wind farm installation and operations, but will even further enhance the natural system underwater, which potentially could even generate new revenue streams (e.g. ideas on 'biodiversity credits' as part of new policy research).

4 Spin off

This project has been a significant catalyst at Fugro for development of technology used for measuring ecological factors. Leadership of this project has also significantly contributed to the development of Fugro's biodiversity policy, understanding of nature based non-financial disclosure requirements, and the development of Fugro's biodiversity measurement strategies applied across multiple sectors. This includes, but not limited to:

- Photogrammetry (2D and 3D) that can be used in earlier phases of offshore wind development for environmental baseline analysis, habitat assessment, coastal resilience, and other areas of hydrography contributing to general understanding of ocean health;
- Autonomous and semi-autonomous eDNA sampling from crewed vessels, autonomous underwater vehicles, and metocean buoys. Including in earlier phases of offshore wind development, coastal resilience, port monitoring, and other areas contribute to general understanding of ocean health; and
- Data sharing as part of Fugro's ongoing commitment to the UN Ocean Decade and partnership with the European Marine Observation Data Network.

Investigation has also been initiated to understand the monitoring needs and pain-points for large-scale ports with regards to species and pollution detection in combination with asset inspection. This exploration is currently in early stages with interviews with Port Environmental Managers as the main activity.

5 Publications

The project will yield the following publications:

- Post Presentation: *Advancing biodiversity monitoring in offshore wind farms with novel technologies: practical and policy challenges and opportunities*
- Author: Daniel Smith, Daniël van Berkel, Pauline Roos, Reindert Nijland, Samantha Kristensen,
- Publication date: 20th March 2024
- Where to find: WindEurope Annual Conference Bilbao 2024

Furthermore Fugro published the project summery on their website:
https://www.fugro.com/news/business-news/2023/bewild-using-edna-to-measure-biodiversity-at-offshore-wind-farms
This publication is also copied by a number of other websites such as: www.energyglobal.com, windpowernl.com, Offshore engineer Magazine, etc. indicating the solid international exposure of the BE WILD project.

The project also includes two PhDs with the following expected publication schedules:

PhD Daniel van Berkel:

Expected title	Publication Date	Publication location
Validation and optimization of native sequencing methods using the critically endangered European sturgeon (*Acipenser sturgeon*) as model organism.	Q3 2024	To be determined.
Improvement of macrobenthic genomic database of (artificial) reefs in the Dutch North Sea.	Q3 2025	To be determined.
Development of macrobenthic community on the scour protection in an OWF using environmental DNA.	Q2 2026	To be determined.
Using native sequencing to determine species composition, abundance and population genetics in an artificial reef.	Q4 2026	To be determined.

PhD Samantha Kristensen:

Expected title	Publication Date	Publication location
Conference presentations:	During the mentioned conferences:	EIMR: Kirkwall, Orkney Scotland and;

- EIMR 2024 (under review) - EASST 2024 (to be submitted Feb 2024)	EIMR: April 15-19 2024 EASST: July 16-19 2024	EASST: Amsterdam
Exploring understandings of marine biodiversity inscribed in the design of emerging monitoring technologies.	To be submitted mid-2024	To be determined.
Exploring the influence of emerging monitoring technologies on discourses within Environmental Impact Assessment.	To be submitted end-2024.	To be determined.
Exploring other ways of knowing and monitoring biodiversity through the use of emerging technologies in other geographical contexts by different stakeholder groups.	To be submitted mid-2025.	To be determined.
To decommission or not? How does eDNA water sampling influence decommissioning processes of offshore infrastructures?	To be submitted mid-2026.	To be determined.