25 Years of Occupational Scientific Diving at RBINS

Symposium

BOOK OF ABSTRACTS

Editor: Alain Norro

Royal Belgian Institute of Natural Sciences
Brussels, Belgium

19 March 2026

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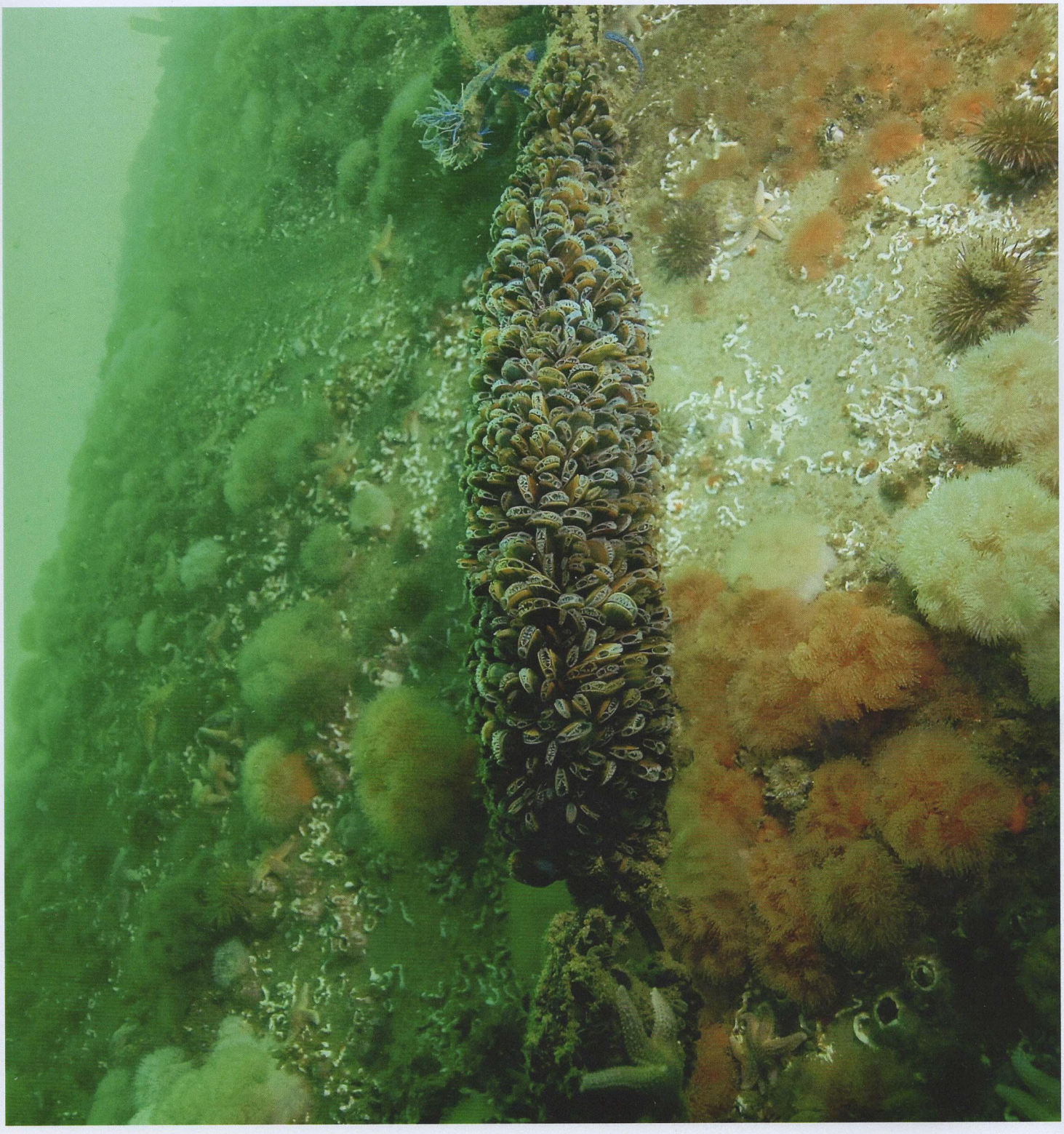

Marine life is covering all the available surface and even more at the foundation D5 at C-Power wind park.

Photos: all photos by Alain Norro (RBINS), identifications by Francis Kerckhof (RBINS).

Cover. Occupational scientific diver along the foundation of the D5 wind turbine at the C-Power wind park.

Legal deposition: D/2026/0039/1

Occupational scientific diver documenting an Aural underwater sound recorder attached to a large tripod C-Power wind park.

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SYMPOSIUM

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25 Years of occupational scientific diving at RBINS.– Symposium 19 March 2026	
Time slot	***Subject***
8h45–9h15	Registration
9h20–9h40	Welcome
9h40–10h00	Introduction. What is occupational scientific diving ?
10h–10h20	15 Year of Fouling Monitoring in Offshore wind farms
10h20–10h40	OUTFLOW: Quantifying the contribution of fouling fauna to the local carbon budget of an offshore wind farm
10h40–11h00	Coffee break

Spiny spider crab, *Maja brachydactyla*, C Power wind park D6.

25 Years of occupational scientific diving at RBINS.– Symposium 19 March 2026	
Authors	***Session Name / Chair***
General Director: M. Van Camp	
A. Norro	
	Scientific output: Jan Vanaverbeke & Steven Degraer (RBINS)
T. Kerkhove & F. Kerckhof	
U. Braeckman, E. Gamela, E. Borger, D. Van den Eynde, S. Bodé, I. Lizaga, P. Boeckx, A. Capet, G. Lacroix & J. Vanaverbeke	

Pouting *Trisopterus luscus* near Belgian North Sea wreck.

Time slot	*Subject*
11h00–11h20	Towards an understanding of the functional effects of offshore wind farms on the marine environment
11h20–11h40	Studying biofouling patterns in the offshore littoral zone: work conducted in the EcoMPV project
11h40–12h00	Life beneath the longlines Diver-operated video transects to evaluate benthic effects of mussel aquaculture in the Belgian North Sea
12h00–12h20	Feasibility of offshore flat oyster restoration: work in the EU Horizon projects UNITED and ULTFARMS
12h20–12h40	Scientific Diving Supporting Multibeam Seafloor Mapping: A Step Back to Revisit the 2004–2010 Experience on the Belgian Continental Shelf
12h40–13h00	Support for RBINS Belgian North Sea fieldwork, Direct in-situ observations, Instrument installation and on-site service/sampling, Search and Recovery of lost equipment
13h–14h	Lunch break

Dahlia anemone, *Urticina felina*, another colour morph, Belwind wind park.

25 Years of Occupational Scientific Diving at RBINS

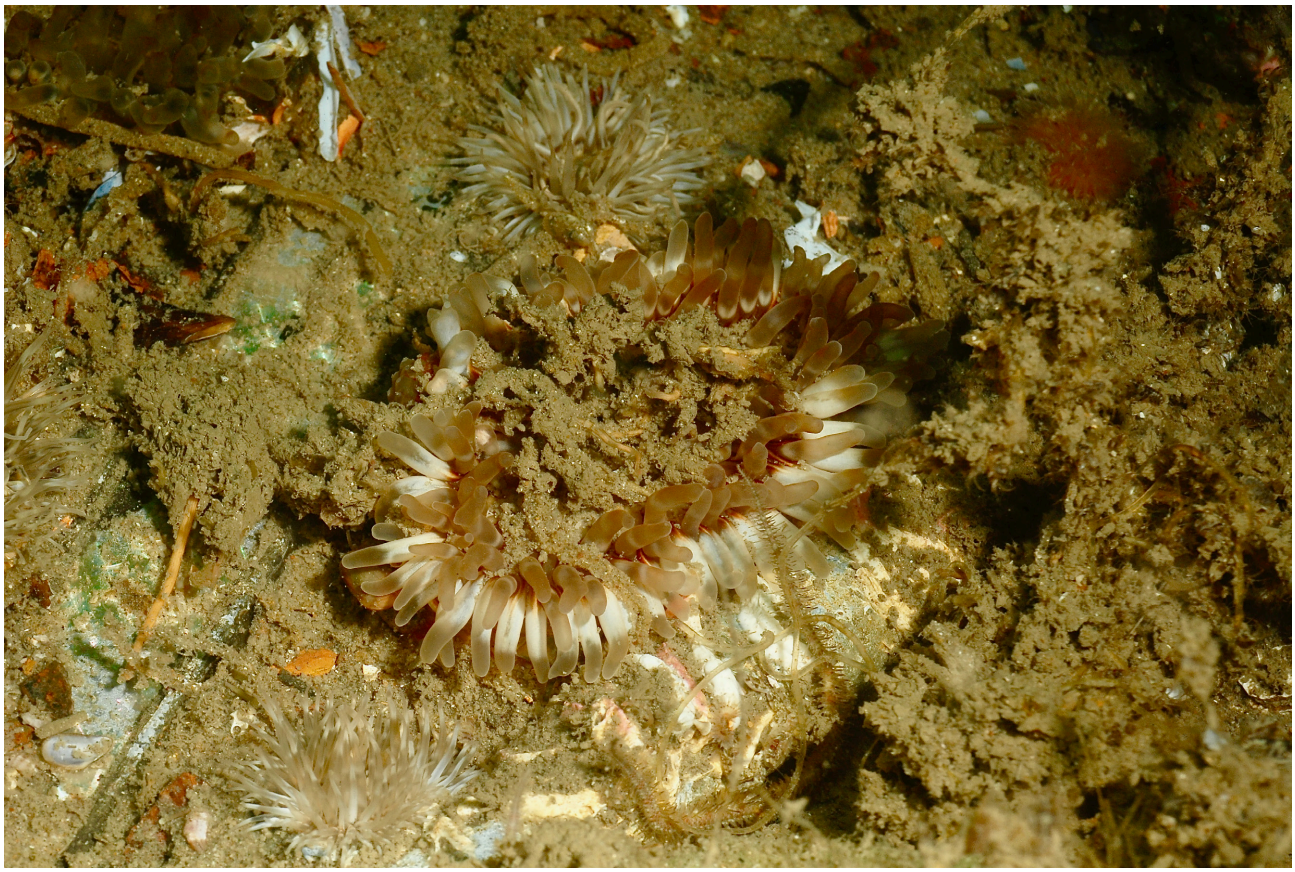
Authors	*Session Name / Chair*
J. Vanaverbeke, U. Braeckman, N. Mavraki, H. Voet , E. Vlaminck, M. Zupan, C.Van Colen, E. De Borger, K. Soetaert, W. De Clerq & S. Degraer	Scientific output: Jan Vanaverbeke & Steven Degraer (RBINS)
T. Kerkhove & W. De Clerk	
W De Clerk & T. Kerkhove	
T. Kerkhove & W. De Clerk	
M. Roche	
A. Norro	

European lobster, *Homarus gammarus*, CPOWER wind park D5.

Time slot	*Subject*
14h00–14h20	Structured training of the occupational scientific diver in Belgium
14h20_14h40	Occupational scientific diving training - Additional training
14h40–15h00	Cruises organised by OSD team in the Belgian Offshore North Sea
15h–15h20	Coffee break

Largely a patch of *Hydractinia echinata* (Snail fur) overgrowing several Volcano barnacles, *Balanus perforatus*, also right under a green sea urchin *Psammechinus miliaris*, Belwind wind park. BBB8.

Authors	*Session Name / Chair*
A. Norro, S.Van Haelst & V. Woit	Training-operation: Alain Norro & Valerie Woit (RBINS)
A. Norro	
A. Norro	



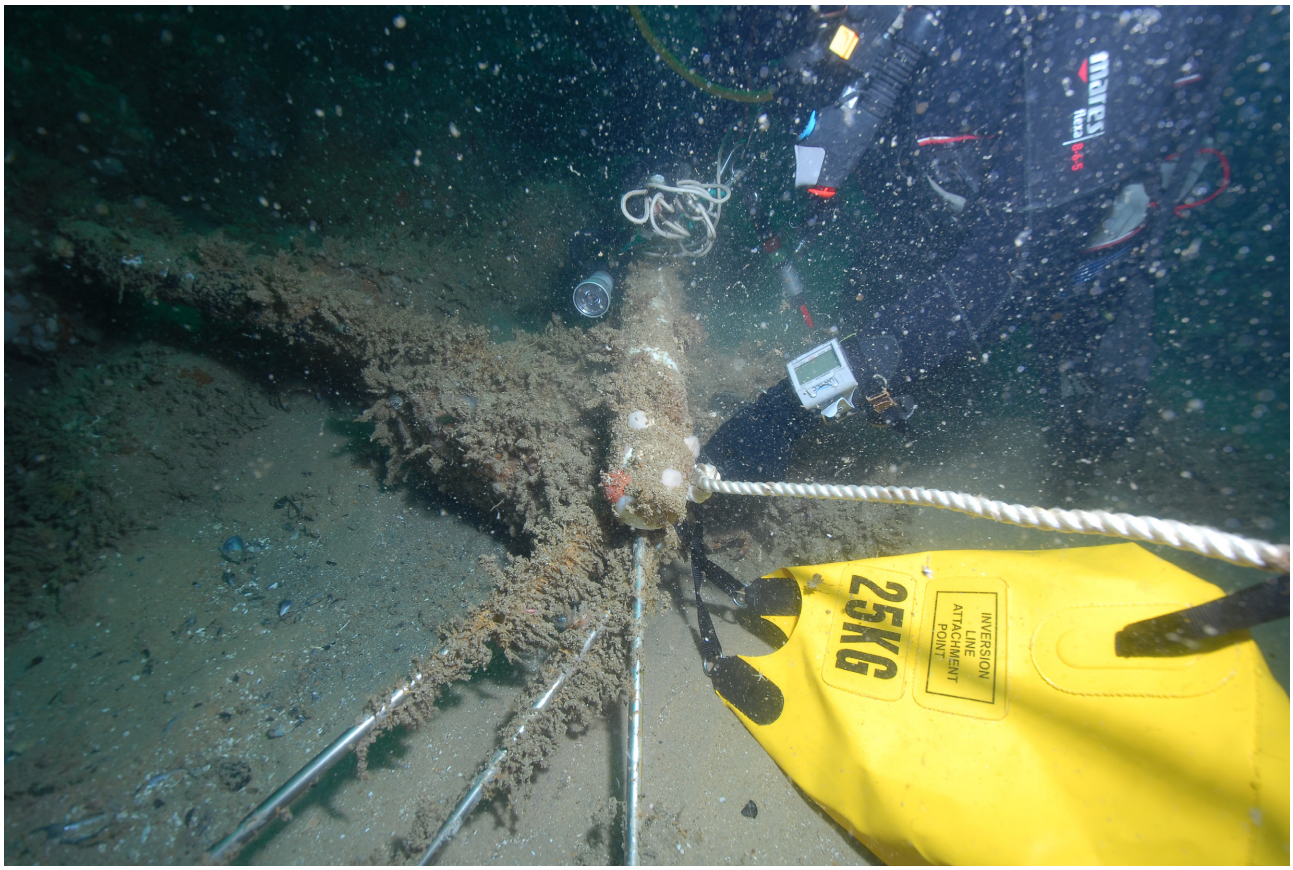
Urticina felina; some Volcano barnacles, *Balanus perforatus* overgrown by *Jassa-turf* and also hidden in the turf some *Cylista troglodytes* formerly *Sagartia troglodytes* or Mud sagartia, Belwind wind park. BBB8.

Time slot	*Subject*
15h40h–16h00	The Belgian level - Belgian Working Group on Scientific Diving
15h20–15h40	VLIZ and RBINS Scientific Diving: 20 Years of Collaboration
16h00–16h20	The Mobility of Institutional Scientific Personnel Utilising Diving in Europe – The European Scientific Diving Panel - ESDP
16h20–16h40	25 Years of Scientific Diving: Expanding Horizons
16:40–17h00	Citizen science and diving as a tool for collecting biotic indices
17h00–17h20	Concluding remarks

Common starfish, *Asterias rubens* and Dahlia anemone, *Urticina felina*, Belwind wind park. BBB8.

25 Years of Occupational Scientific Diving at RBINS

Authors	*Session Name / Chair*
D. Cox	Sector management D. Cox (Belspo)
S.Van Haelst , K. Deneudt , P. Hendriks, D. Marsham and J.Reubens	
A.Norro and J.P Féral	
	What next ?
N. Jacobsen	
P. Panneels	
All	



Occupational scientific diver at work recovering instrument with lift bag, Belwind wind park.

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Foreword – 25 Years of Occupational Scientific Diving in Belgium

Occupational scientific diving in Belgium is founded on a solid base of expertise across both the recreational diving sector and academic fieldwork at the heart of the Royal Belgian Institute of Natural Sciences. What began as a specialised research practice has, through challenges, innovation and perseverance, grown into a fully recognised professional activity in Belgium and across Europe over the last 25 years.

Around 2003, emerging legal and safety constraints revealed the need for clearer regulations. This catalysed the creation of both a Belgian and European professional sector for scientific diving, including a collaboration with the Flanders Marine Institute on this matter. In 2008, the Belgian branch found its home at BelSPO, while at the European level, the discipline continued to evolve within the European Science Foundation and, later, the European Marine Board.

A key early insight was the necessity for this professional sector to become an independent discipline, clearly separated from the recreational diving industry. Training programmes were therefore developed according to European competency levels, delivered exclusively by scientists who are also certified instructors or instructor trainers. This approach ensured that training aligned with scientific needs and rigorous safety expectations, free from the limitations of recreational training agencies.

For many years, the Belgian part of the North Sea served as a natural testing ground for this emerging sector. Working aboard the RV Belgica and later the RV Zeeleeuw and RV Simon Stevin, the team established a clear guiding principle: safety comes before scientific objectives and before logistics. It is this uncompromising approach to safety that continues to define how scientific diving projects are designed and executed today.

Despite the professionalism, it remained a challenge to overcome the persistent ‘leisure image’ associated with diving in discussions with administrative bodies or research colleagues. Nevertheless, through consistent effort and a strong safety culture, the sector built a solid reputation, demonstrating its capacity to perform demanding and high-risk tasks, including operations within offshore wind farms.

Today, as we look back on this rich history, we celebrate not only the milestones but also the people, the expertise, the scientific achievements and the resilience that have carried this sector forward over a quarter of a century. This report reflects that evolution; from ecological research and offshore monitoring to training, sector governance, technological developments and international collaboration.

May this milestone of 25 years of occupational diving in Belgium be a launching point for the next 25 years, filled with new insights, increased cooperation and a continued commitment to safety, quality and scientific excellence.

Steven DEGRAER
Operational Director at the Royal Belgian Institute of Natural Sciences
4 March 2026

Foreword

Scientific diving is an unparalleled tool for investigation in coastal, lacustrine, and river waters. Despite this, it is often misperceived as a mere recreational or hazardous activity. By the late 1970s, such prejudice increasingly hindered professional practice across several Member States. In response, researchers, engineers, and technicians organised under the EU's MAST programme to develop legal frameworks to dismantle regulatory barriers. It quickly became evident that without such measures, personnel mobility across Europe would be stifled. As recognised in the legislation of those states that acknowledge it, scientific diving remains uniquely tailored to each discipline—conducted **for scientists, by scientists**.

A consensus soon emerged: only a **universally endorsed reference system** could streamline administrative procedures. Belgium, alongside France and other nations discussed today, worked to define "occupational" competency levels which, linked to a national certificate from a recognised authority, serve as a genuine "professional scientific passport".

To achieve this, it was essential for **each country's occupational scientific diving community** to be represented by a **single, unified national committee**. These bodies vouch for both the diver's proficiency and their national certification, provided they hold a valid medical certificate. Given the heterogeneity among Member States, the European Scientific Diving Committee (ESDC), established in the early 1990s **within the EU directive and recommendation framework**, was tasked with disseminating up-to-date information. A milestone was reached in 2008 when the ESDC became a panel of the European Science Foundation's (ESF) Marine Board, gaining vital visibility. This **European Scientific Diving Panel** (ESDP) now legitimises the standards and competency levels endorsed by the ESDC since 2000.

Initially, a few countries legally recognised the specificity of scientific diving as distinct from commercial or recreational diving, **from which it is fundamentally different**. While only France, Germany, and the UK originally had specific legislation, this number has grown to include Belgium, where the Belgian Working Group on Scientific Diving became operational in 2008.

This symposium summarises the efforts of the ESDP representative for Belgium, who helped establish the national framework. The objective of this meeting is to review progress over the past 25 years, identify requirements for future development, and highlight pitfalls to avoid, ensuring that diving remains a vital scientific tool and that the mobility of occupational divers is sustained.

Jean-Pierre FÉRAL
ESDP Chairman
7 December 2025

25 Years of Occupational Scientific Diving at RBINS

Alain M.J. NORRO [1,*]

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In 1999, the Management Unit of the Mathematical Model of the North Sea and the Schelde Estuary (MUMM), which manages the Research Vessel *Belgica*, launched a call for interest in civilian scientific diving operations from the vessel, registered as a Belgian navy ship. Many issues had to be addressed, resulting in a first one-week cruise in July 2000, which was postponed in July 2001 due to adverse weather. The target was to start a faunal inventory of a Belgian water shipwreck. This was seen as a feasibility study for that research tool. From that moment until 2004, a cruise was granted each year to develop this highly efficient method of sampling hard substrates. In 2004, the first funded project, BEWREMABI SPSD II, was awarded, enabling us to begin occupational scientific diving aboard the R/V *Zeeleeuw* managed by VLIZ, a partner of the BEWREMABI Project. From that moment onward, the number of projects involving this tool increased; see the project table. Among others, it made possible the rediscovery, after Gilson, of the refuge zones of the Hinderbank (project HINDERS, SPSD II, BELSPO). Intensive fieldwork using an in-house-developed methodology enables the collection of unique samples for the long-term project WinMon.BE (2008-2025), which monitors the newly implemented Belgian energy production zone and other projects, with a focus on targeted monitoring. At the same time, RBINS initiated the structuring of the Belgian professional sector for managing occupational scientific diving (BWGSD), hosted by BELSPO. In 2008, RBINS organised the first training for personnel affiliated with a Belgian scientific institution, building on the 2003 training and aligned with the European Scientific Diving Panel (BE founding member) Level of competency for scientific diving at work, level ESD. In 2025, RBINS, with the support of VLIZ, organised the 17th edition of the BSD core training and trained approximately 100 occupational scientific divers. The RBINS scientific diving team operated more than 4500 MD (Man Dive), mostly in the offshore North Sea, providing support to more than 25 funded national or international research projects, and all that safely - no major accident, few incidents- keeping in mind the 'Safety First' philosophy that is the fundamental of this activity.

Occupational Scientific Diving is defined as "*Occupational Scientific Diving (OSD) is science-led diving and is needed to support professional research and education and protect, conserve, and monitor the natural and cultural heritage environment. Operated as a work activity, OSD is not to be confused with recreational nor commercial diving. OSD exists in a health and safety framework that involves certified occupational scientific divers, diving officers, hyperbaric physicians, scientific project leaders, heads of laboratories, administrators, and legislators*." Feral & Norro (2024).

Queen scallop *Aequipecten opercularis* with a small Common starfish, *Asterias rubens*, Belwind wind park BBB8.

15 years of fouling monitoring in offshore wind farms

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In the Belgian part of the North Sea, 399 offshore wind turbines are currently installed. The first turbines were installed in 2008 on gravity-based foundations. Since then, the epifaunal community colonising these foundations and the scour protection layer surrounding these foundations, has been monitored in the framework of the WinMon.BE programme. Monitoring of this artificial hard-substrate community has been conducted in a standardised manner by the occupational scientific dive team. Scientific divers collected three scrape samples at 15 m depth using a quadrat frame, along with three stones of the scour protection layer. These samples were preserved and subsequently analysed in the laboratory, whereby all organisms were identified, counted and, where relevant, weighed. This approach has enabled the investigation of the epifaunal community succession over a 15-year period - a time frame that is unique of its kind.

A typical succession pattern emerged: an initial community consisting of early colonisers in the first two years, which developed into a highly species-diverse community after about seven years. However, only a few species dominated the community. Subsequently, species diversity declined and the community became dominated by a limited number of species, of which the blue mussel *Mytilus edulis*, the plumose anemone *Metridium senile* and the tube forming amphipod *Jassa herdmani* were the most dominant.

The high abundances of epifaunal species on the turbine foundations and surrounding scour protection layers contribute to the so-called 'artificial reef effect' that offshore wind farms display. However, a comparison with natural hard substrates in the Belgian part of the North Sea, the gravel beds, showed that offshore wind farms cannot substitute these natural habitats. Gravel beds support a far more diverse and distinct epifaunal community. Even after 15 years of succession, the epifaunal assemblages on offshore wind farm structures do not resemble those found on natural substrates.

OUTFLOW: Quantifying the contribution of fouling fauna to the local carbon budget of an offshore windfarm

Ulrike BRAECKMAN [1,2*], Esther Cepeda GAMELA [1,2,3], Emil DE BORGER [2], Dries VAN DEN EYNDE [1], Samuel BODÉ [3], Ivan LIZAGA [3], Pascal BOECKX [3], Arthur CAPET [1,4], Geneviève LACROIX [1] & Jan VANAVERBEKE [1,2]

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The OUTFLOW project (Belgian Science Policy Office – funded research project 2021 – 2025) aimed at increasing the understanding of carbon cycling within and beyond the scale of an offshore wind farm. The interdisciplinary research consortium adopted an approach that integrated field-validated and model-supported assessments of how fouling fauna on offshore wind turbines alter carbon dynamics in and around offshore wind farms (OWFs) in the Belgian Part of the North Sea. The field work around the foundations and scour protection layers of offshore wind turbines was conducted with skillful help of the Belgian Occupational Scientific Diving Team and the VLIZ Scientific Diving Team which operate as services provided by EMBRC Belgium. This allowed detailed observations of the local alterations to carbon dynamics in an OWF. Our results reveal that fouling communities create novel trophic pathways that channel water-column production to the seafloor, leading to localised and temporal increases in benthic organic matter and measurable changes in processing of carbon in the benthic food-web. However, biogeochemical modelling of the observed patterns in the sediment porewater nutrients indicated that the fast mineralisation processes in permeable sediments and the dynamic hydrodynamic environment strongly limit long-term carbon storage. While OWFs induce clear ecological and biogeochemical effects at the scale of individual turbines and wind farms, our upscaling efforts suggest a relatively modest broader regional effect on carbon cycling. The findings highlight the importance of considering both physical sediment properties and hydrodynamic processes when assessing the potential of OWFs to influence carbon cycling or contribute to carbon storage.

Towards an understanding of the functional effects of offshore wind farms on the marine environment

Jan VANAVERBEKE [1,2,*], Ulrike BRAECKMAN [1,2], Ninon MAVRAKI [3], Helena VOET [1,2], Ellen VLAMINCK [1], Mirta ZUPAN [1,2], Carl VAN COLEN [1], Emil DE BORGER [3], Karlien SOETAERT [3], Wannes DE CLERQ [1] & Steven DEGRAER [1]

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The expansion of offshore wind farms (OWFs) is causing canges in structural biodiversity due to the introduction of artificial hard substrates in natural sandy environments. While these structural effects are well documented, understanding their implications for ecosystem functioning requires researcj along a mechanistic framework linking biodiversity patterns to ecological processes. This is typically obtained through controlled laboratory and field experiments. Given the logistical challenges conducting experiments in offshore wind farms of with relevant organisms collect in OWFs, the expertise of highly skilled scientific divers is needed for standardized and safe in situ sampling.

Here, we connected structural biodiversity changes in OWFs with ecosystem functioning by adopting a food-web approach. Field data were collected by scientific divers from turbine-associated habitats, including scrape samples along depth gradients of turbine foundations, rocks from scour protection layers, and cores and airlift samples from sediments within close vicinity of the edge of scour protection zones. Following sample collection, stable isotope analyses were performed to investigate trophic linkages and carbon pathways. The resulting dataset enabled the first data-driven characterization of an offshore wind farm ecosystem. This included an isotopic niche based description of the food web, highlighting the role of trophic plasticity allowing the dense co-occurence of the fouling fauna on turbines, and the role of the scour protection layers as habitat providing a wide and abundant basis for the local food web. A first full offshore food web model reveals that OWF fauna act as a local carbon pump, by filtering large amounts of water and repacking organic matter as faecal pellets that can be deposited at the sea floor. Experimental work suggested increased carbon assimilation and sediment enrichment under projected climate change conditions. Moving back into the field, a diver-supported experiment confirmed that increased complexity of the scour protection layers seems to lead to an increased and more diverse availability of prey items, paving the road towards nature inclusive design measures that are rooted in sound ecological knowledge.

Studying biofouling patterns in the offshore littoral zone: work conducted in the EcoMPV project

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EcoMPV (Eco-designing marine photovoltaic installations), a research project funded by the Belgian Energy Transition Fund (FPS Economy), aims to deepen the knowledge about environmental challenges related to offshore floating solar. One of the knowledge gaps the project addresses is the artificial habitat provision for colonising fauna, for which *in situ* field experiments were conducted inside a Belgian offshore wind farm. For this, EcoMPV benefited greatly from the help of the Belgian occupational scientific dive team.

The field experiments consisted of three 'Littoral Modules', part of the Artificial Hard Substrate Garden (AHSG) of the Institute of Natural Sciences. Each module is a buoy-based platform, moored to the seafloor by a bio-facilitating anchor. This experimental setup was installed 55 km offshore, near an offshore wind farm. The littoral modules serve as floating platforms onto which settlement plates were attached. These plates consist of three different materials and were positioned over three levels of the littoral zone. As such, the settlement patterns of fouling species could be studied *in situ*, thereby representing actual conditions for offshore floating structures. The plates were retrieved one-by-one by scientific divers, while the scientific dive team also collected physical scrape samples and video samples from the bio-facilitating anchors. Conducting experimental work so far offshore has been challenging, but the first sampling campaign was successful, yielding valuable data on offshore biofouling patterns, including species not previously detected at that distance. Currently, the littoral modules are retrieved, and the bio-facilitating anchors are planned to be retrieved in the coming period with the help of the scientific dive team.

Life beneath the longlines
Diver-operated video transects to evaluate benthic effects of mussel aquaculture in the Belgian North Sea

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The Westdiep Sea Farm is the first commercial offshore mussel (*Mytilus edulis*) farm in the Belgian part of the North Sea and introduces artificial hard substrates into a soft-sediment environment. To assess potential benthic ecosystem responses to offshore longline mussel farming, diver-operated video transects were implemented as one component of the environmental monitoring. The focus of this approach is to evaluate the accumulation of dislodged mussels beneath longlines and the associated attraction of mobile epibenthic macrofauna and demersal fish.

The monitoring approach consists of 40 m-video transects, conducted by scientific divers beneath the longline infrastructure using a camera system equipped with lights and scaling lasers. Surveys were performed prior to installation (T0) and at multiple times following the expansion of the aquaculture farm, allowing for the temporal assessment of benthic habitat modification, mussel reef formation and benthic community composition. A T0 survey conducted in 2023 characterised the concession area as a sandy seabed dominated by brittle stars and starfish, with limited fish observations. Low visibility and tidal dynamics required methodological evaluation and refinement for future monitoring campaigns.

Follow-up monitoring in 2025 included both an impact area beneath the longlines and a control area. Preliminary observations indicate a substantial accumulation of dislodged mussels in the impact area, although repeated monitoring will be required to evaluate whether these accumulations persist over seasons. Signs of organic enrichment were visible, accompanied by higher abundances, especially of juveniles, of *Asterias rubens*. Detailed analysis of the video footage is still ongoing. This monitoring could not have been possible without the expertise and dedication of the Belgian occupational scientific dive team.

Feasibility of offshore flat oyster restoration: work in the EU Horizon projects UNITED and ULTFARMS

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The Horizon 2020 project UNITED and the Horizon Europe project ULTFARMS all benefited greatly from the help of the Belgian occupational scientific dive team. For both projects, *in situ* field experiments were conducted inside the Belgian offshore wind farms. The field experiments of UNITED and ULTFARMS focus on the feasibility of restoring European flat oyster (*Ostrea edulis*) reefs.

For UNITED, oyster restoration tables were installed in an offshore wind farm on the scour protection of two turbines. These tables contained each six gabions filled with substrate (stones) and adult oysters. The goal was to study the survival, growth, recruitment and larval dispersal of these oysters, and at the same time study the developing epibenthic communities associated with the oysters and the substrate. For this purpose, up to two gabions per table were retrieved annually by scientific divers. Currently, one or two gabions remain in each table and are scheduled for retrieval in the coming year, within the framework of ULTFARMS. Results are already promising, showing good survival of the adult oysters, and settlement and growth of oyster spat on the substrates.

In ULTFARMS, the recruitment of flat oysters was studied in more detail. For this, in-water moorings, part of the Artificial Hard Substrate Garden (AHSG) of the Institute of Natural Sciences, with clay settlement plates, were deployed, together with adult oysters. The idea was that the larvae produced by the adult oysters would settle on the clay plates. The clay plates, which also had different surface complexities to study general fouling patterns, were retrieved one-by-one by scientific divers. Although the number of oyster spat found on the settlement plates was low, the experimental design itself proved to be promising for studying oyster recruitment and general biofouling patterns.

Scientific Diving Supporting Multibeam Seafloor Mapping: A Step Back to Revisit the 2004–2010 Experience on the Belgian Continental Shelf

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This contribution revisits the period 2004–2010, during which multibeam echosounder mapping of the Belgian Continental Shelf relied on close collaboration with occupational scientific divers.

Multibeam systems (100 kHz EM1002, later 300 kHz EM3002D) provided bathymetry and backscatter data with metric spatial accuracy, enabling delineation of acoustically homogeneous seabed classes. Yet interpretation required equally precise in situ observations, an operational challenge offshore. Internal class variance, sediment heterogeneity, and residual artefacts often limited the ability to make unequivocal sediment attributions based on acoustic data alone.

To address these limitations, divers conducted targeted ground-truth surveys on gravel beds, sand banks and interbank channels. Positional coherence between acoustic footprints and diver observations was essential. A GPS-mounted surface buoy towed by the diver, synchronised with video and photographs, ensured geo-referenced seabed descriptions with an accuracy of approximately 10 m, compatible with multibeam spatial resolution at the time, and allowed direct comparison between the acoustic signal and the seabed reality.

In situ sand-thickness measurements revealed clear relationships between backscatter strength and sediment cover, distinguishing thin sand veneers (0–15 cm) over gravel from thicker deposits. In such areas, Van Veen grab sampling is often ineffective, as very thin sand layers cannot be properly characterised. Direct diver measurements, therefore, improved ground-truthing and enabled reliable differentiation between these zones. Diver observations also highlighted the importance of hard substrates, refuge areas and wrecks as biodiversity hotspots.

The experience gained provides a solid methodological baseline. With today's decimetric MBES positioning, improved diver tracking, and rigorous video georeferencing, integration between acoustic cartography and scientific diving should yield greater spatial coherence and interpretive reliability.

Support for RBINS Belgian North Sea fieldwork, direct *in-situ* observations, instrument installation and on-site service/sampling, search and recovery of lost equipment

Alain M.J. NORRO [1,*]

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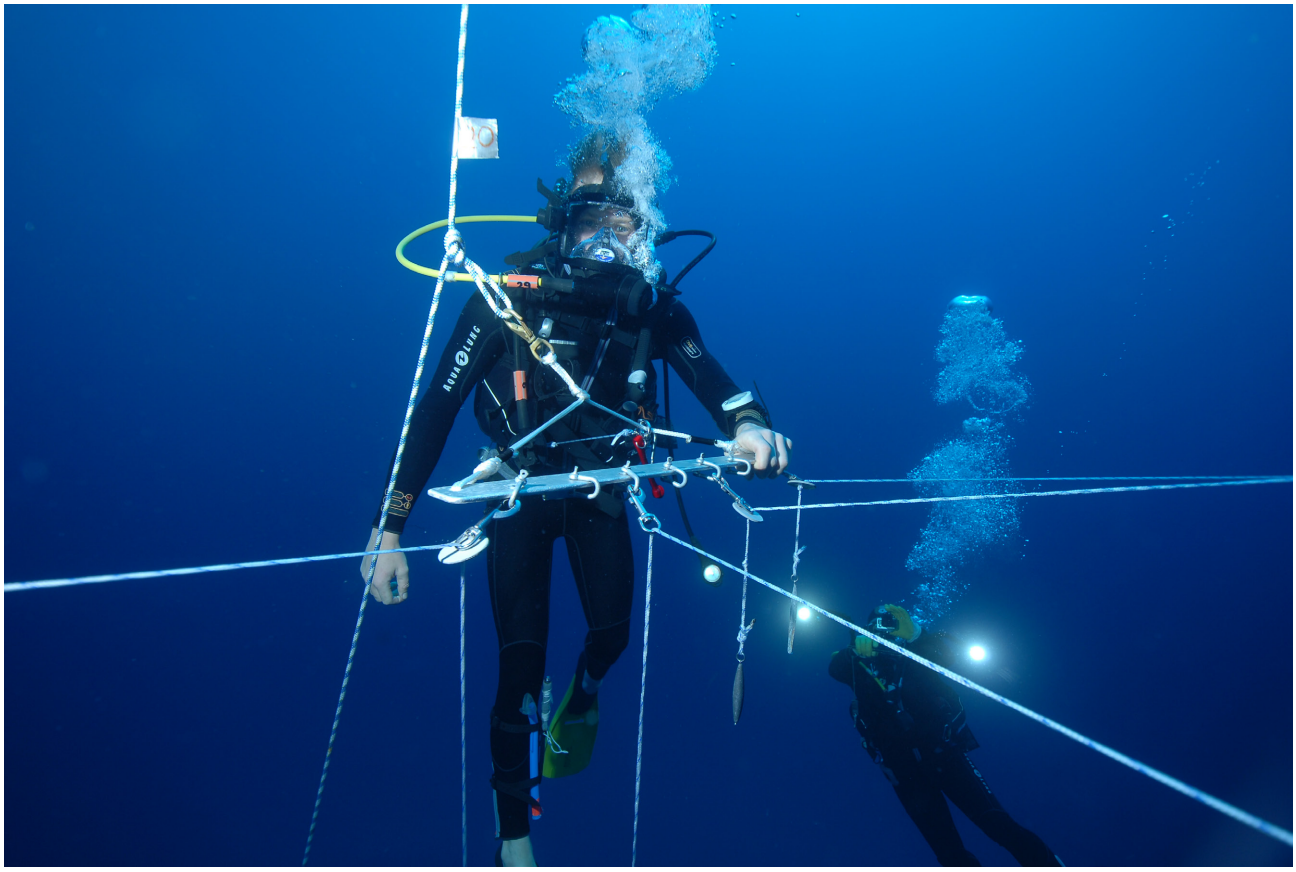
Scientific research conducted by the Institute of Natural Sciences requires underwater fieldwork in the Belgian zone of the North Sea. **The RBINS occupational scientific diving team supports that scientific research**. This include many tasks such as, fish sensing by direct observation and/or video transect, sampling of soft sediment and hard substratum by air-lift, coring at locations where remote operation from research vessel is not possible, direct sand thickness measurement and georeferenced video of the sea floor, video surveys and photogrammetry modeling, faunal inventory, sampling to cages maintained in the water column or to tables installed on the seafloor or even massive anchors. Those structures must be sampled several times per year and recovered at the end of the experiment. Video surveys have become a standard component of sampling. Search and recovery of lost equipment are also among the team's main tasks today.

For underwater acoustic research, autonomous recorders are often moored on the seafloor, or cabled stations are installed at fixed positions. The Jomopans project installed a permanent recording station at the Westhinder monopile (MP7). The station included two hydrophones moored away and cabled to the monopile.

Our **team's support** is needed at all stages of the work, from experiment design and comprehensive planning to execution at sea. Planning diving work within the Belgian energy production zone is challenging from an administrative perspective. The activity and the team must be cleared by the workplace concessioner before any work can start. The obtention of a work permit is subject to the submission and acceptance of a complete **work method statement** document. On the day of the operation, a strict communication protocol must be followed between the research vessel and the concessioner's coordinator at sea.

Many specific skills are required from the team members, extending well beyond the already high technical diving level required to dive from large vessels in the offshore North Sea. If training for the main tasks is part of the structured or additional training we provide, the team can also be trained at any time for any new specific task.



Safety diver using full face mask during training on the blue water sampling experiment (Calvi-Corsica).

Structured training of the occupational scientific diver in Belgium

Alain NORRO [1,*], Sven VAN HAELST [2] & Valerie WOIT [1]

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[2] *VLIZ, Flanders Marine Institute, Ostend, Belgium.*
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Occupational scientific diving is a field of activity undertaken by professional scientists, University students in aquatic sciences, and laboratory personnel at scientific institutions. Training for the occupational scientific diver is a legal requirement in Belgium. The Code of Well-being at Work -hyperbaric work- is part of the Belgian law and requires that training of the workers must be taken prior to any work starting. This is the employer's responsibility.

The Belgian Working Group on Scientific Diving (BWGSD) was created at the initiative of RBINS in 2007 and hosted by BELSPO, which has been authorised by the FPS Employment, Labour and Social Dialogue, holding the Code of Well-being at Work, to deliver the professional competency for scientific diving. This authorisation was gained based on a training compliant with the (A)ESD competency levels for scientific diving at work from the European Scientific Diving Panel.

The training program by RBINS for BELSPO started in 2009, and today, with the help of VLIZ (From 2016 onward) includes two components.

1. On the one hand, the structured course meets the ESD standards (full compliance). This comprises a 4-day theoretical training session at Vrije Universiteit Brussel (VUB) as a 3-ECTS-credit course, with 75 h of study time. For the practical component, the two-week intensive practical internship covers all skills required at the ESD competency level and is organised to achieve 20 scientific dives in clear water. In 2026, It is planned to organise (RBINS & VLIZ) the 18th edition of the structured training BSD (Belgian Scientific Diver).

2. On the other hand, the specific training includes first the "Offshore North Sea" that focuses on all the needs and environmental conditions of scientific work conducted in the Belgian part of the North Sea. Secondly, the ABSD training covers the training & assessment required to be a 'dive supervisor' in occupational scientific diving. Those additional training sessions are organised today only at the diver's employer's request. Continuous training may fall into specific training.

Over the years, the program has evolved and has been supplemented by additional sessions on tether diving, with a practical on blue water diving, a combined task allowing to better assess the applicant's ability to work safely in a team. The human factor in occupational scientific diving was introduced in the theoretical lessons. Applicants are asked to produce, as a team, a 5-minute film illustrating one of the skills they learned during the training.

Entry conditions for the training include a diving level equivalent to CMAS 2* and a valid first-aid certificate, including oxygen administration. Applicants acknowledged by a Belgian scientific institution must be medically fit (Code of Well-being at work) and insured for occupational scientific diving. The BWGSD organises the formalities related to the certification of candidates, thereby formally establishing their professional competence as described in the Code of Well-being at Work.

Occupational Scientific Diving training in Belgium
Additional training

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The professional training that RBINS organises for the BWGSD is not limited to structured training (see above). Under Belgian law, the diver's employer is responsible for ensuring that training is completed before work begins. For specific training, such as Offshore North Sea operations or the dive supervisor role known as ABSD in our sector, if the training cannot be organised in-house, the diver's employer can submit a request to the working group. Inside the group of occupational scientific diving Belgium has, few ABSD, instructor or instructor trainer that can provide additional training on many aspects like Basic or advanced first aid, full-face mask, dry-suit diving or side mount diving or Diver Propulsion Vehicle (DPV) but not only and also some more technical specialties are possible like mixed-gas diving permitting to enlarge the zone of operation to the mesophotic zone using open-circuit trimix diving or closed circuit rebreather or). The organisation of such additional training is to be arranged between the institution requiring the training and the institution with the resources to deliver it.

For some time, the working group has also been conducting training at a quarry in Belgium to support the community and provide additional scientific dives to help maintain certifications.

Cruises organised by OSD team in the Belgian Offshore North Sea

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The Institute's main operational area is the Belgian North Sea.

Many projects required the support of the occupational scientific dive team. From 2008 onward, most cruises were conducted within the Belgian energy production zone.

Few platforms have been used by the diving team, including the former RV *Belgica* and the new vessel from 2022 onward, RV *Zeeleeuw*, replaced by RV *Simon Stevin*, both operated by VLIZ and many vessels of opportunity, *Stream*, *Aquatrot*, *Aquafly* both latter from OMS services Oostende, *GeOXYZ 10, Divestar*, the *Zeetiger* from VLOT and the *Ephyra*.

From 2001 to date, about half of the planned cruises have not sailed due to weather-related conditions and, at times, mechanical failures.

Altogether, the team could operate a little less than 800 dives, accounting for more than 4500 MD (Man Dive). We will discuss the few incidents we have faced over the last 25 years of operations.

Sandalled anemone, *Actinothoe sphyrodeta* (the white colour morph that we see now more and more in our waters, e.g., on wrecks), *Birkenfels* wreck.

The Belgian Working group on scientific diving (BWGSD)

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By the end of the 1990s and the beginning of the 2000s, scientific diving started to be used as part of research projects and monitoring activities, among others at RBINS-MUMM.

In the early years, the scientific diving community in Belgium was small, and given the very specific and marginal nature of this activity, it was felt that there was no need for an association or formal grouping of scientific divers in Belgium.

However, around 2008, the use of scientific diving techniques increased significantly, creating the need for a structured coordination, and training. Developments at the European level — including the creation of the European Scientific Diving Panel — and the need to ensure effective Belgian participation further strengthened the case for establishing a formal structure.

At the beginning of 2009, at the proposal of RBINS-MUMM, the Belgian Science Policy Office (BELSPO) established the Belgian Working Group on Scientific Diving (BWGSD) within the framework of the Interdepartmental Coordination Commission of the Mathematical Model of the North Sea (ICC).

Chaired by RBINS, the BWGSD brought together all universities and research institutions using scientific diving in their work, the operators of research vessels, and representatives of Defense. Specific Terms of Reference for the group were developed.

The group organises and manages the annual training courses and the issuance of the "Belgian Scientific Diver (BSD)" and "Advanced Belgian Scientific Diver (ABSD)" certificates, both fully equivalent to the European standards set by the ESDP and compliant with Belgian legal requirements.

The BWGSD serves also as the representative body of the Belgian scientific diving sector at the necessary national and international levels.

VLIZ and RBINS Scientific Diving: 20 Years of Collaboration

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More than 20 years ago, in August 2004, VLIZ carried out its first scientific dives. From the very start, scientific diving by VLIZ was organised as a collaborative effort, and over the years it has involved many Flemish and Belgian institutions (e.g. UGent, ILVO, Onroerend Erfgoed, UCL, RBINS, Belgian defence) and volunteer divers. In the early days, dives were conducted from the RV Zeeleeuw, and later from the RV Simon Stevin and Abbé Mann, strengthening logistics capabilities and reducing operational risks.

Scientific diving at VLIZ started with the BEWREMABI project, in which divers mapped the biodiversity on shipwrecks in the Belgian Part of the North Sea. In 2007 the Belgian Working Group on Scientific Diving (BWGSD) was established, initiated by RBINS and hosted by BELSPO. The BWGSD integrated occupational diving regulations from the Belgian legislation and developed the Belgian sector of occupational scientific diving. From 2009 onwards, RBINS/ BWGSD has organised a yearly training for Belgian scientific divers which is fully compliant with the (A)ESD competency levels for scientific diving at work defined by the European Scientific Diving Panel.

Since the establishment of the BWGSD the close collaboration between the scientific divers from VLIZ and RBINS continued after BEWREMABI through joint research projects (Artificial reefs II, Persuade, OUTFLOW,…) and PhD research, while also supporting each other with diver capacity and ship time when needed. Since 2018, VLIZ has taken an active role in training new scientific divers and co-organises the training programme with RBINS. On top of all the scientific output based on this long-standing cooperation, working together in the often harsh conditions of the North Sea have created a strong network of scientific divers across the institutes, strengthening both research capacity and operational safety.

The Mobility of Institutional Scientific Personnel Utilising Diving in Europe – The European Scientific Diving Panel - ESDP

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In the late 1980s, initial discussions on the mobility of scientific divers within European Union member states were initiated within the framework of the European MAST project. This issue emerged as an increasing number of scientists reported growing difficulties in obtaining permits to conduct underwater observations, sampling, or experimentation outside their respective national waters.

The EU facilitated the establishment of an expert group to propose solutions to this restrictive administrative situation. At the time, the European landscape of professional diving was highly fragmented: while certain member states—notably **France, the Netherlands, Germany, Sweden, and Belgium**—had robust legislation on the matter, others, such as **Portugal, Italy, and Luxembourg**, lacked such a legal framework.

Although training and education remain a prerogative of individual member states (under the **principle of subsidiarity**), the mobility of professional workers is a highly sensitive subject. The EU has addressed this through various legislative instruments, most notably **Directive 2005/36/EC**, followed by **Directive 2013/55 EU**.

On 24th October 2000, the European competency levels for occupational scientific diving—the **European Scientific Diver (ESD)** and **Advanced European Scientific Diver (AESD)**—were formally ratified during the Banyuls-sur-Mer meeting (France) by the following countries: BE, FI, FR, GER, GR, IE, IT, NO, the NL, PL, PT, SE, and the UK. Subsequently, on 21st October 2008, the **European Scientific Diving Panel (ESDP)** was established under the aegis of the European Science Foundation's Marine Board (now the **European Marine Board**). Shortly thereafter, on 16th February 2009, the **Belgian Working Group on Scientific Diving** was created by the Institute of Natural Sciences (**RBINS**) under the auspices of **BELSPO**.

Since the inception of the ESDP, Belgium has been a highly active member, spearheading numerous initiatives. These include the development of key consultation documents:

- **Doc 3**: Guidelines for Scientific Diving from large Research Vessels.
- **Doc 4**: ESDP Best Practice for using Closed-Circuit Rebreather for Scientific Diving at work.
- **Doc 7** (published last summer): Mobility of Occupational Scientific Divers in Europe.

Currently, Belgium chairs a working group dedicated to training and the compliance of certification issuance among ESDP members, with the aim of streamlining the movement of scientific personnel across Member States.

Dahlia anemone, *Urticina felina* and a Plumose anemone *Metridium senile* + several barnacles Volcano barnacles, *Balanus perforatus,* and even a Blue mussel, *Myitlus edulis* all largely hidden under the *Jassa*-turf.

25 Years of Scientific Diving: Expanding Horizons

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Over 25 years, the Institute of Natural Sciences has built a respected scientific diving program, particularly focused on the Belgian Part of the North Sea. It provides an occupational scientific diving framework with a strong focus on safety that enables scientific divers to integrate into complex global collaborations. Scientific diving is highly adaptable to various environments and research contexts. Joining forces in international collaborations opens up opportunities for new research lines and allows divers to gain experience in various environments and with diverse methodologies. These experiences strengthen a diver's adaptability, problem-solving capacity, and situational awareness — all essential for safe and effective underwater research. Examples of collaborations, spanning citizen science initiatives and occupational scientific diving operations, showcase these benefits while highlighting the important role of standard operating procedures and shared equipment configurations. These facilitate the safe and effective execution of complex tasks, even under adverse conditions and are essential not only for international collaborations but also for the scientific diving operations in the Belgian Part of the North Sea. Moving forward, priorities for the Institute of Natural Sciences will be to increase internal scientific diving capacity and strengthen international collaborations, including through existing frameworks such as the European Scientific Diving Panel, while maintaining the strong safety culture built over 25 years.

Citizen science and diving as a tool for collecting biotic indices

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The diving group (GBRS), founded in 1955, has, as its name suggests, a scientific focus. The group's founders were primarily researchers and scientists in biology, geology, and related fields, working as assistants or professors at Belgian universities and A. Capart at the Institute of Natural Science (RBINS). Currently, the number of GBRS members directly involved in university research has declined significantly, but the motivation to engage in scientific research remains strong.

This motivation, shared by many current members, has evolved into a focus on raising awareness among the general public through science participation. Promoting knowledge of Belgian freshwater fauna and flora also means introducing and facilitating the collection of scientific data.

Within this framework, for several years, the GBRS has organised citizen-science days specifically for divers and other interested individuals, including those already involved in natural history. Certain Belgian bodies of water and quarries, rich in marine life, offer particularly interesting locations to demonstrate that diving is more than just blowing bubbles. Scuba diving is thus used as a tool in the service of a cause, in this case, a citizen science activity. After an hour underwater collecting aquatic life samples, the group, along with other participants, spent considerable time identifying the samples and the animals collected. The ultimate goal is to classify the quality of the water body based on biological diversity using the biotic index. What particularly motivates us is that this activity can be repeated several times in the same body of water at different times of year, for several consecutive years, or even in several quarries, and each time, a biotic index can be calculated, without requiring a professional scientist.

Thus, the GBRS has adapted to its time while preserving its core identity.

Selected bibliography

A1 PAPERS

2002

Massin C., Mallefet J. & Norro A. 2002. Scientific diving, a new tool for monitoring in-situ North Sea biodiversity: preliminary results. *Bulletin de l'Institut royal des Sciences naturelles de Belgique/Bulletin van het Koninklijk Belgisch Instituut voor Natuurwetenschappen, Biologie* 72 Suppl.: 17–18.

Massin C., Norro A. & Mallefet J. 2002. Biodiversity of a wreck from belgian continental shelf:monitoring using scientific diving. Preliminary results. *Bulletin de l'Institut royal des Sciences naturelles de Belgique/Bulletin van het Koninklijk Belgisch Instituut voor Natuurwetenschappen, Biologie* 72: 67–72.

2006–2008

Zintzen V., Massin C., Norro A. & Mallefet J. 2006. Epifaunal diversity on shipwrecks: first results for the Belgian continental shelf. *Hydrobiologia* 555: 207–219.

Zintzen V., Norro A., Massin C. & Mallefet J. 2007. The hydroid *Tubularia indivisa (*Cnidaria, Tubulariidae) plays a structural role on artificial habitat communities. *Marine Biology* 153: 405–420. https://doi.org/10.1007/s00227-007-0819-5

Zintzen V., Norro A., Massin C. & Mallefet J. 2008. Spacial variability of epifaunal communities from artificial habitat: shipwrecks in the Southern Bight of the North Sea. *ECSS* 76: 327–344.

2010

Kerckhof F., Rumes B., Jacques T., Degraer S. & Norro A. 2010. Early development of the subtidal marine biofouling on a concrete oGshore windmill foundation on the Thornton Bank (southern North Sea)/First monitoring results. *International Journal of the Society for Underwater Technology* 29 (3): 1–13.

2011

Reubens J.T., Degraer S. & Vincx M. 2011. Aggregation and feeding behaviour of pouting (*Trisopterus luscus*) at wind turbines in the Belgian part of the North Sea. *Fisheries Research* 108: 223–227. https://doi.org/10.1016/j.fishres.2010.11.025

2013

Norro A., Rumes B. & Degraer S. 2013. Differentiating between underwater construction noise of monopile and jacket foundations for offshore windmills, A case study from the Belgian part of the North Sea. *The Scientific Journal* 2013: e897624. https://doi.org/10.1155/2013/897624

2014

Brabant R., Degraer S. & Rumes B. 2014. Windmolenparken in het Belgisch deel van de Noordzee: De ecologische effecten onder de loep. *Natuur.Focus* 13 (1): 4–10.

Coates D.A., Deschutter Y., Vincx M. & Vanaverbeke J. 2014. Enrichment and shifts in macrobenthic assemblages in an offshore wind farm area in the Belgian part of the North Sea. *Marine Environmental Research* 95: 1–12. https://doi.org/10.1016/j.marenvres.2013.12.008

Reubens J., De Rijcke M., Degraer S. & Vincx M. 2014. Diel variation in feeding and movement patterns of juvenile Atlantic cod at offshore wind farms. *Journal of Sea Research* 85: 214–221. https://doi.org/10.1016/j.seares.2013.05.005

Reubens J., Degraer S. & Vincx M. 2014. The ecology of benthopelagic fishes at offshore wind farms: a synthesis of 4 years of research. *Hydrobiologia* 727: 121–136. https://doi.org/10.1007/s10750-013-1793-1

2015

De Mesel I., Kerckhof F., Norro A., Rumes B. & Degraer S. 2015. Succession and seasonal dynamics of the epifauna community on offshore wind farm foundations and their role as stepping stones for non-indigenous species. *Hydrobiologia* 756: 37–50. https://doi.org/ 10.1007/s10750-014-2157-1

2016

Norro A. 2016. The closed circuit rebreather (CCR): is it the safest device for deep scientific diving? *Underwater Technology* 34 (1): 31–38. https://doi.org/10.3723/ut.34.031

2018

Kerckhof F., Coolen J.W.P., Rumes B. & Degraer S. 2018. Recent findings of wild European flat oysters *Ostrea edulis* (Linnaeus, 1758) in Belgian and Dutch offshore waters: new perspectives for offshore oyster reef restoration in the southern North Sea. *Belgian Journal of Zoology* 148 (1): 13–24. https://doi.org/10.26496/bjz.2018.16

2020

Degraer S., Carey D.A., Coolen J., Hutchison Z., Kerckhof F., Rumes B. & Vanaverbeke J. 2020. Offshore wind farm artificial reefs affect ecosystem structure and functioning: A synthesis. *Oceanography* 33 (4): 48–57. https://doi.org/10.5670/oceanog.2020.405

Fowler A.M., Jørgensen A.-M., Coolen J.W.P., Jones D.O.B., Svendsen J.C., Brabant R.,

Rumes B. & Degraer S. 2020. The ecology of infrastructure decommissioning in the North Sea: what we need to know and how to achieve it. *ICES Journal of Marine Science/Journal du Conseil international pour l'Exploration de la Mer* 77(3): 1109–1126. https://doi.org/10.1093/icesjms/fsz143

Hutchison Z.L., Bartley M.L., Degraer S., English P., Khan A., Livermore J., Rumes B. & King J.W. 2020. Offshore wind energy and benthic habitat changes: lessons from Block Island wind farm. *Oceanography* 33 (4): 58–69. https://doi.org/10.5670/oceanog.2020.406

Mavraki N., Degraer S., Moens T. & Vanaverbeke J. 2020. Functional differences in trophic structure of offshore wind farm communities: a stable isotope study. *Marine Environmental Research* 157: e104868. https://doi.org/10.1016/j.marenvres.2019.104868

Mavraki N., De Mesel I., Degraer S., Moens T. & Vanaverbeke J. 2020. Resource niches of co-occurring invertebrate species at an offshore wind turbine indicate a substantial degree of trophic plasticity. *Frontiers in Marine Science* 7: e379. https://doi.org/10.3389/fmars.2020.00379

Mavraki N., Degraer S., Vanaverbeke J. & Braekman U. 2020. Organic matter assimilation by hard substrate fauna in an offshore wind farm area: a pulse chase study. *ICES Journal of Marine Science* 77 (7–8): 2681–2693. https://doi.org/10.1093/icesjms/fsaa133

Merchant N., Andersson M., Boxc T., Le Courtois F., Cronin D., Holdsworth N., Kinneging N., Mendes S., Merck T., Mouat J., Norro A., Ollivier B., Pinto C., Stamp P. & Tougaard J. 2020. Impulsive noise pollution in the Northeast Atlantic: Reported activity during 2015–2017. *Marine Pollution Bulletin* 152: e110951.

2021

Kok A.C.M, Bruil L., Berges B., Sakinan S., Debusschere E., Reubens J., de Haan D., Norro A. & Slabbekoorn H. 2021. An echosounder view on the potential effects of impulsive noise pollution on pelagic fish around windfarms in the North Sea. *Environmental Pollution* 290: e118063.

2022

Buyse J., Hostens K., Degraer S. & De Backer A. 2022. Offshore wind farms affect the spatial distribution pattern of plaice *Pleuronectes platessa* at both the turbine and wind farm scale. *ICES Journal of Marine* Science 79 (6): 1777–1786. https://doi.org/10.1093/icesjms/fsac107

Coolen J.W.P., Vanaverbeke J., Dannheim J., Garcia C., Birchenough S.N.R., Krone R. & Beermann J. 2022. Generalized changes of benthic communities after construction of wind farms in the southern North Sea. *Journal of Environmental Management* 315: e115173.

Voet H.E.E., Van Colen C. & Vanaverbeke J. 2022. Climate change effects on the ecophysiology and ecological functioning of an offshore wind farm artificial hard substrate community. *Science of The Total Environment* 810: e152194. https://doi.org/10.1016/j.scitotenv.2021.152194

2023

Buyse J., Reubens J., Hostens K., Degraer S., Goossens J. & De Backer A. 2023. Movement patterns of plaice *Pleuronectes platessa* in relation to an offshore wind farm: evidence of high residency, site fidelity and use of the scour protection as a feeding hotspot. *ICES Journal of Marine Science* 82 (4): 1–13. https://doi.org/10.1093/icesjms/fsad179

Buyse J., Hostens K., Degraer S., De Troch M., Wittoeck J. & De Backer A. (2023). Increased food availability at offshore wind farms affects trophic ecology of plaice Pleuronectes platessa. *Science of The Total Environment* 862: e160730. https://doi.org/10.1016/j.scitotenv.2022.160730

Feral J.-P. & Norro A. 2023. Specific initial training standards are needed to dive for science in Europe, Occupational vs. Citizen Science Diving. *Frontiers in Marine Sciences* 10: e1134494. https://doi.org/10.3389/fmars.2023.1134494

Voet H.E.E., Vlaminck E., Van Colen C., Bodé S., Boeckx P., Degraer S., Moens T., Vanaverbeke J. & Braeckman U. 2023. Organic matter processing in a [simulated] offshore wind farm ecosystem in current and future climate and aquaculture scenarios. *Science of The Total Environment* 857: e159285. https://doi.org/10.1016/j.scitotenv.2022.159285

Voet H., Soetaert K., Moens T., Bodé S., Boeckx P., Van Colen C., Vanaverbeke J. 2023. N2O production by mussels: Quantifying rates and pathways in current and future climate settings. *Frontiers in Marine Science* 10: e1101469. https://doi.org/10.3389/fmars.2023.1101469

Zupan M., Rumes B., Vanaverbeke J., Degraer S. & Kerckhof F. 2023 Long-term succession on offshore wind farms and the role of species interactions. *Diversity* 15 (2): e288.

2024

Basan F., Fischer J.-G., Putland R., Brinkkemper J., de Jong C.A.F., Binnerts B., Norro A., Kühnel D., Ødegaard L.-A., Andersson M., Lalander E., Tougaard J., Griffiths E.T., Kosecka M., Edwards E., Merchant N.D., de Jong K., Robinson S., Wang L. & Kinneging N. 2024. The underwater soundscape of the North Sea. *Marine Pollution Bulletin* 198: e115891.

Dairain A., Voet H., Vafeiadou A.-M., De Meester N., Rigaux A., Van Colen C., Vanaverbeke J. & Moens T. 2024 Structurally stable but functionally disrupted marine microbial communities under a future climate change scenario: Potential importance for nitrous oxide emissions. *Science of The Total Environment* 907: e167928. https://doi.org/10.1016/j.scitotenv.2023.167928

Feral J.-P. & Norro A. 2024. Standards of initial training in Occupational Scientific Diving (OSD), a necessity for the mobility of scientists in Europe. *Cahiers de Biologie Marine* 65: 269–277. https://doi.org/10.21411/CBM.A.AAB43A40

Zupan M., Coolen J., Mavraki N., Degraer S., Moens T., Kerckhof F., Lopez L.L. & Vanaverbeke J. 2024. Life on every stone: Characterizing benthic communities from scour protection layers of offshore wind farms in the southern North Sea. *Journal of Sea Research* 201: e102522. https://doi.org/10.1016/j.seares.2024.102522

2025

De Borger E., van Oevelen D., Mavraki N., De Backer A., Braeckman U., Soetaert K. & Vanaverbeke J. 2025. Offshore wind farms modify coastal food web dynamics by enhancing suspension feeder pathways. *Communications Earth & Environment* 6: 1–16. https://doi.org/10.1038/s43247-025-02253-w

De Cauwer K., Courtens W., De Witte B., De Schrijver C., Degraer S., Deneudt K., Desmidt J., Desmit X., Devos K., Everaert G., Francken F., Haelters J., Hostens K., Kapasakali D., Kerckhof F., Kerkhove T., Kint L., Knockaert M.,

Lagaisse R., Legrand S., Maes J., Montereale Gavazzi G., Moreau K., Norro A., Ochetti F.E., Parmentier K., Podholova P., Ponsar S., Rombouts I., Rumes B., Schallier R., Stienen E., Terseleer N., Vanavermaete D., Vanermen N., Van de walle M., Van der Zande D., Vanhalst K., Van Hoey G., Van Lancker V., Van Nieuwenhove A., Verlé K. & Verstraete H. 2025. Samenvatting van de staat van het marien milieu. *In*: *Mariene Strategie Deel 1 voor de Belgische mariene wateren. Staat van Belgische mariene wateren, goede milieutoestand en milieudoelen. Kaderrichtlijn Mariene Strategie – Artikel 8, 9 en 10*: 11–60.

Dannheim J., Kloss P., Vanaverbeke J., Mavraki N., Zupan M., Spielmann V., Degraer S., Birchenough S.N.R., Janas U., Sheehan E., Teschke K., Gill A.B., Hutchison Z., Carey D.A., Rasser M., Buyse J., van der Weide B., Bittner O., Causon P., Krone R., Faasse M., Wrede A. & Coolen J.W.P. 2025. Biodiversity Information of benthic Species at ARtificial structures – BISAR. Scientific Data 12: e604. https://doi.org/10.1038/s41597-025-04920-1

Jammar C., Reynés-Cardona A., Vanaverbeke J., Lefaible N., Moens T., Degraer S. & Braeckman U. 2025. Decadal trends in macrobenthic communities in offshore wind farms: Disentangling turbine and climate effects. *Journal of Sea Research* 203: e102557. https://doi.org/10.1016/j.seares.2024.102557

Lefaible N., Van Colen C., Jammar C., Vanaverbeke J., Moens T., Van Haelst S., Norro A., Degraer S. & Braeckman U. 2025. Laying out the foundations: assessing the spatial extent and drivers of offshore wind turbine artificial reef effects on soft sediments. *Journal of Sea Research* 208: e102631. https://doi.org/10.1016/j.seares.2025.102631

REPORTS, ABSTRACTS & THESES

Aoufi S., Rumes B., Debusschere E., Paoletti S. & Degraer S. 2024. Determining the effects of operational offshore wind farms on harbour porpoise distribution and foraging behaviour in the North Sea. *In*: Mees J. *et al.* (eds) *Book of Abstracts – VLIZ Marine Science Day, 6 March 2024, Oostende.* VLIZ Special Publication, 91.

Degraer S. & Brabant R. (eds) 2009. *Offshore Wind Farms in the Belgian Part of the North Sea. State of the Art after Two Years Environmental Monitoring*.

Degraer S. *et al.* (eds) 2010. *Offshore Wind Farms in the Belgian Part of the North Sea: Early Environmental Impact Assessment and Spatio-temporal Variability.*

Degraer S. *et al.* (eds) 2011. *Offshore Wind Farms in the Belgian Part of the North Sea: Selected Findings from the Baseline and Targeted Monitoring.*

Degraer S. *et al.* (eds) 2012. *Offshore Wind Farms in the Belgian Part of the North Sea: Heading for an Understanding of Environmental Impacts.*

Degraer S. *et al.* (eds) 2013. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Learning from the Past to Optimise Future Monitoring Programmes.*

Degraer S. *et al.* (eds) 2016. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Environmental Impact Monitoring Reloaded.*

Degraer S. *et al.* (eds) 2017. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: A Continued Move towards Integration and Quantification.*

Degraer S. *et al.* (eds) 2018. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Assessing and Managing Effect Spheres of Influence.* Memoirs on the Marine Environment.

Degraer S. *et al.* (eds) 2019. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Making a Decade of Monitoring, Research and Innovation.* Memoirs on the Marine Environment.

Degraer S. *et al.* (eds) 2020. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Empirical Evidence Inspiring Priority Monitoring, Research and Management.* Memoirs on the Marine Environment.

Degraer S. *et al.* (eds) 2021. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Attraction, Avoidance and Habitat Use at Various Spatial Scales.* Memoirs on the Marine Environment.

Degraer S. *et al.* (eds) 2022. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Getting Ready for Offshore Wind Farm Expansion in the North Sea.* Memoirs on the Marine Environment.

Degraer S. *et al.* (eds) 2023. *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Progressive Insights in Changing Species Distribution Patterns Informing Marine Management.* Memoirs on the Marine Environment.

Degrendele K., Houziaux J.-S., Norro A. & Roche M. 2007. *Intérêt de la plongée scientifique pour la caractérisation de visu et le contrôle des classes acoustiques définies par sondeur multifaisceaux. Bilan général des campagnes de mesures 2005–2007*. Fonds pour l'exploitation du sable, ministère des Affaires économiques. Bruxelles. 35 pp.

Féral J.P & Norro A. 2023. European standards for initial training in *occupational* scientific diving, a necessity, and a guarantee for the mobility of scientists and effective research in the coastal environment. *In*: *Abstract of the 7th European Conference on Scientific Diving, Roscoff, France*.

Folegot T., Clorennec D., Norro A., Gill A. & Thomsen F. 2016. *Modelling the Risk of Noise Exposure to Marine Life during Offshore Wind Farms Construction and Operation*. Abstract ESAL conference.

Houziaux J.-S., Roche M., Zintzen V., Norro A., Mallefet J., Kerckhof F. & Degrendele K. 2008. *Gravel habitats characterisation*. Abstract at WGMHM.

Houziaux J.-S., Kerckhof F., Degrendele K., Roche M. & Norro A. 2008. *The Hinder Banks: Yet an Important Area for the Belgian Marine Biodiversity?* SPSD II, Belspo, May 2008. 248 pp.

Kerckhof F., Norro A., Jacques T.G & Degraer S. 2009. Early colonisation of a concrete Offshore windmill foundation by marine biofouling on the Thorton Bank (southern North Sea): 39–51.

Kerckhof F., Degraer S., Norro A. & Rumes B. 2012. Offshore intertidal hard substrata: a new habitat promoting non-indigenous species in the Southern North Sea. *CM Documents – ICES*, CM 2012(O:21). International Council for the Exploration of the Sea, Copenhagen.

Kerkhove T.R.H., Kapasakali D.-A., Kerckhof F. & Degraer S. 2022. A comparison between the epifaunal biodiversity of shipwrecks and offshore wind farms in the Belgian part of the North sea. *In*: Degraer S., Brabant R., Rumes B. & Vigin L. (eds) *Environmental Impacts of Offshore Wind Farms in the Belgian Part of the North Sea: Getting Ready for Offshore Wind Farm Expansion in the North Sea*: 69–79. Memoirs on the Marine Environment. Royal Belgian Institute of Natural Sciences, OD Natural Environment, Marine Ecology and Management: Brussels. ISBN 978-9-0732-4267-8.

Mallefet J., Zintzen V., Vanden Berghe E., Vincx M., Massin C. & Norro A. 2008. *Belgian Shipwreck: Hotspots for Marine Biodiversity (BEWREMABI)*. SPSD II Belspo, May 2008. 153 pp.

Norro A. 2013. The Belgian scientific diving training program. *In*: Lang M.A. & Sayer M.D.J. (eds) *Proceedings Joint International Scientific Diving Symposium American Academy of Underwater Sciences and European Scientific Diving Panel*. Curaçao, October 24–27, 2013: 207–209.

Norro A. 2016. The Closed Circuit Rebreather (CCR) safest device for deep scientific diving? *In*: *Abstract of the 2nd European Conference on Scientific Diving, Kristineberg, Sweden.*

Norro A. 2019. Training occupational scientific diving: The scheme developed during the last 10 years in Belgium. *In*: *Abstract of the 5th European Conference on Scientific Diving, Sopot Poland*.

Norro A. 2023. European best practice for using Closed-Circuit Rebreather for Scientific diving at work. The ESDP consultation document. *In*: *Abstract of the 7th European Conference on Scientific Diving, Roscoff, France*.

Norro A. 2023. La plongée scientifique. *In*: *Abstract du 3ème congrès international scientifique francophone de médecine subaquatique et hyperbare*. Tunis Tunisie.

Norro A. (editor) 2024. *ESDP Best Practice for Using Closed-Circuit Rebreather for Occupational Scientific Diving at work*. European Scientific Diving Panel' Consultation document n°4. 21 pp. https://doi.org/10.5281/zenodo.11115845

Norro A. & Féral J.P. 2021. The Establishment in Europe of the Common Practices for the recognition of European competency levels for scientific diving at work (ESD&AESD). *In*: *Abstract of the 6th European Conference on Scientific Diving, Freiberg Germany* (Online).

Norro A. & Féral J.P. 2023. More than 20 years of training in occupational scientific diving at work in Europe. The European Scientific Diving Panel (ESDP) model. *In*: *Abstract of the ScienceDiver Conference, Malta*.

Norro A. & Féral J.P. 2024. Iso standards for scientific diving; Are those standards addressing Occupational Scientific Diving or Citizen Science Diving? *In*: *Abstract of the 8th European Conference on Scientific Diving Heraklion, Crete 22–26 April 2024*.

Norro A. & Hocdé R. 2017. *A European Competency Level Applied to the Use of the Closed Circuit Rebreather in Scientific Diving at Work. First Step. Highlighting the Best Practice*. 3rd European Conference on Scientific Diving abstract. Funchal, Madeira/Portugal.

Norro A. & Kerckhof F. 2009. Off-shore windmills monitoring using scientific diving technique. *In*: *Abstract of the ISOSD-2009 conference Helsinki, Finland*.

Norro A. & Mallefet J. 2012. *Scientific Diving Techniques*. Belgian scientific diver training course session 2012. Coursebook. MUMM 09/201. 162 pp.

Norro A. & Mallefet J. 2013. *Scientific Diving Techniques*. Belgian scientific diver training course session 2013. Coursebook. MUMM 09/2013. 187 pp.

Norro A. & Mallefet J. 2014. *Scientific Diving Techniques*. Belgian scientific diver training course session 2014. Coursebook. MUMM 09/2014. 192 pp.

Norro A. & Mallefet J. 2015. *Scientific Diving Techniques*. Belgian scientific diver training course session 2015. Coursebook. MUMM 09/2015. 212 pp.

Norro A. & Van Haelst S. 2018. *Scientific Diving Techniques*. Belgian scientific diver training course session 2018. Coursebook. MUMM 09/2018. 190 pp.

Norro A. & Van Haelst S. 2019. *Scientific Diving Techniques*. Belgian scientific diver training course session 2019. Coursebook. MUMM 09/2019. 110 pp.

Norro A. & Van Haelst S. 2021. *Scientific Diving Techniques*. Belgian scientific diver training course session 2021. Coursebook. MUMM 09/2021. 110 pp.

Norro A., Lenikki J & De Greef C. 2010. *Scientific Diving Techniques*. Belgian Scientific Diver training course 201.0 Workbook. Mumm 2010. 186 pp.

Norro A., Caramanna G. & Germonpré P. 2011. *Scientific Diving Techniques*. Belgian scientific diver training course session 2011. Coursebook. MUMM 09/201. 153 pp.

Norro A., Degrendele K.,Versteeg V.,Vercruysse V. & Roche M. 2011. Marine habitat mapping ground truth. Testing the position accuracy of a geo-localisation system used for *in-situ* sampling against a 'state of the art' acoustic USBL device. *In*: *ISOSD-2011 Conference Lecce, Italy.*

Norro A., Mallefet J. & Van Haelst S. 2016. *Scientific Diving Techniques*. Belgian scientific diver training course session 2016. Coursebook. MUMM 09/2016. 212 pp.

Norro A., Mallefet J. & Gatti J. 2017. *Scientific Diving Techniques*. Belgian scientific diver training course session 2017. Coursebook. MUMM 09/2017. 192 pp.

Rumes B., Debusschere E., Reubens J., Norro A. & Deneudt K. 2017. The influence of pile driving noise on harbour porpoises. *In*: Mees J. *et al.* (eds) *Book of Abstracts – VLIZ Marine Scientist Day. Brugge, Belgium, 3 March 2017.* VLIZ Special Publication, 79.

PhD THESES

Zintzen V. 2007. *Biodiversity of Shipwrecks from the Southern Bight of the North Sea*. UCL.

Reubens J. 2013. *The Ecology of Benthopelagic Fish at Offshore Wind Farms: toward an Integrated Management Approach*. UGENT.

Coates D. 2014. *The Effects of Offshore Wind Farms on Microbenthic Communities in the North Sea*. UGENT.

Mavraki N. 2020. *On the Food-Web Ecology of Offshore Wind Farms, the Kingdom of Suspension Feeders*. UGENT.

Voet H. 2023. *Combined Effects of Climate Change, Offshore Wind Farms and Aquaculture on Marine Ecosystem Functioning*.

Buyse J. 2023. *Ecological Impacts of Offshore Wind Farms on Flatfish with Emphasis on Plaice* Pleuronectes platessa*, a Species of Commercial Interest in the Southern North Sea*.

Vlaminck E. 2023. *Ecosystem Functioning in Offshore Windfarms: Integrating Ocean Warming and Acidification Effects on Macrofauna Ecophysiology, Behavior and Biogeochemistry*. UGENT.

Zupan M. 2023. *Towards Optimizing the Opportunities and Minimizing the Risks of Offshore Wind Farms for the Benthic Environment*. UGENT.

Lefaible N. 2026. *Benthic Footprints of Marine Industries: Offshore Energy and Deep-seabed Mining*. UGENT.

ONGOING

Cepeda Gamelia E. *Quantifying the Role of Offshore Wind Fouling Fauna on the Local Carbon Budget (Provisional)*. UGENT.

Reynés Cardon A. *Marine Ecosystem Functioning under Anthropogenic Pressure: Applying a Food Web Approach*. UGENT.

MASTER THESES (MSc)

Debosschere J. 2017. *The Harbour Porpoise (*Phocoena phocoena*): Consequences of Anthropogenic Underwater Sound on Their Ecological Value*. MSc Thesis. Universiteit Antwerpen/Universiteit Gent/Vrije Universiteit Brussel, Antwerp, Ghent, Brussels. 50 pp + annexes.

Augustijns T. 2018. *Harbour Porpoises in the Belgian Part of the North Sea: Using Passive Acoustic Monitoring to Determine Spatio-temporal Patterns in Distribution and Feeding Behaviour*. MSc Thesis. Faculty of Sciences, Biology Department, Research Group Marine Biology, Ghent. 47 pp.

Buyse J. 2018. *Monitoring of Harbour Porpoise (*Phocoena phocoena*) Density in the Belgian Part of the North Sea Using Aerial Surveys and Passive Acoustic Monitoring*. MSc Thesis. Oceans & Lakes, Interuniversity Master in Marine and Lacustrine Science and Management, Antwerp, Ghent and Brussels.

Piesinger N. 2019. *Determining the Impact of Pile-driving Activity on the Spatio-temporal Distribution of Harbour Porpoises (*Phocoena phocoena*) in the Belgian Part of the North Sea*. MSc Thesis. Ghent University, Ghent. 46 pp.

Debaveye L. 2022. *Effects of Altered Vessel Traffic (and Anthropogenic Ocean Noise) on the Presence of Harbour Porpoises in the Belgian Part of the North Sea*. MSc Thesis. Universiteit Antwerpen/Ghent University/Vrije Universiteit Brussel. 38 pp.

Trikannad A.P. 2024. *Influence of Mature Epibenthic Fouling Communities on Colonisation Patterns in New Offshore Wind Farms*. MSc thesis. 22 pp.

Selected project list of the RBINS occupational scientific diving team involvement

Project Name	***Project Timing***	***Funding Agency***	***Full Name***
APELAFICO	2021–2025	NWO (NL)	Acoustic ecology of PELAgic FIsh COmmunities: A study into the effects of construction and operation of wind farms
BACKSCATTER	2004–2010	fund_sand_extraction FPS Economy Belgium	Multiberan seafloor mapping- Ground-truthing backscatter by diver operated video-
BEWREMABI	2004–2007	BELSPO	Belgian Shipwreck: Hotspots for Marine Biodiversity
DEMASK	2024–2027	EU - INTERREG	Development and evaluation of noise management strategies to keep the North Sea healthy
ECOMPV	2022–2026	Energy Transition fund Belgium	Eco-designing marine photovoltaic installations
EDEN 2000	2019–2022	FPS Health, Food Chain Safety and Environment	Exploring options for a nature-proof development of offshore wind farms inside a Natura 2000 area
FACE-IT	2016–2021	BELSPO	Functional biodiversity in a Changing sedimentary Environment: Implications for biogeochemistry and food webs in a managerial setting
HINDERS	2004–2007	BELSPO	The Hinder banks: Yet an important area foor the Belgian marine biodiversity
JOMOPANS	2018–2021	EU - INTERREG	Joint Monitoring programme for ambiant noise North Sea
MaRVEN	2013–2015	EU FP7	Environmental Impacts of Noise, Vibrations and Electromagnetic Emissions from Marine Renewable Energy
MonWin	2005–2026	WinMon.BE	Belgian Offshore Wind Farm Monitoring
OUTFLOW	2021–2025	BELSPO	Quantifying the cOntribUTion of Fouling fauna to the Local carbon budget of an Offshore Wind farm
PERSUADE	2017–2021	BELSPO	Experimental Approaches toward future sustainable use of North Sea Artificial Hard Substrates
PUREWIND	2023–2026	JPI Ocean via BELSPO	Impact of sound on marine ecosystems from offshore wind energy generation

Project Name	***Project Timing***	***Funding Agency***	***Full Name***
UltFarms	2023–2026	EU Horizon 2020	Circular Low Trophic Offshore Aquaculture In Wind Farms And Restoration Of Marine Space
UNITED	2020–2023	EU Horizon 2020	Multi-Use offshore platforms demoNstrators for boostIng cost-effecTive and Eco-friendly proDuction in sustainable marine activities
WestDeep	2020….	Colruyt Group	Westdeep Sea Farm monitoring

Brown crab or edible crab, *Cancer pagurus*, CPOWER wind park D5.

Pouting *Trisopterus luscus* along the monopile BBA5 Belwind wind park.

Diver using a full face mask during ABSD training.

Dive team training for the skill 'small scale cartography' on a sandy patch between a *Posidonia oceanica* sea-bed BSD training (Calvi, Corsica).