Living Windfarms Project: North Sea Artificial Reef Pilot

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IMPORTANT INFORMATION

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ExoLodge artificial reef unit being deployed at North Sea gas platform K5PK.

Contents

1. Introduction

As part of the Offshore Wind Growth Partnership (OWGP) funded Living Windfarms Project, and in partnership with TotalEnergies EP Nederland and The Rich North Sea (De Rijke Noordzee), Exo Engineering have designed, manufactured and deployed artificial reef units with nature-inclusive design (NID) features at a test site within the operation a TotalEnergies platform in the North Sea. These artificial reef units were named “ExoLodges” and will be referred as this from here on. The ExoLodges will be regularly monitored to assess the biodiversity associated with them and compare this to appropriate control locations at the test site. This report outlines the deployment of the artificial reef units and the results from baseline biodiversity monitoring of the site.

2. Project goal

The main project goals that can be achieved through this pilot are to collect data to help answer the following questions:

- Does the inclusion of nature inclusive designs (NID) benefit the marine life associated with offshore infrastructure?
- Does the additional cost of nature inclusive design translate into a proportional biodiversity gain?
- Can monitoring of the reef units be successfully integrated into the existing ROV survey program of TotalEnergies EP Nederland?

3. Research questions

3.1 Main research question

Is the biodiversity of the ExoLodges significantly different from the biodiversity associated with existing marine infrastructure after 5 years?

3.2 Sub-research questions

- Is the species richness of the ExoLodges different from the species richness of the control locations*?
- Does the mean percentage cover of sessile benthic species colonising the ExoLodges differ from the control locations?
- Does the community structure associated with the ExoLodges differ from the community structure of the control locations?

- What is the ecological succession of species on the ExoLodges over time? (Assuming that control locations have reached a climax community)
- Will invasive species establish themselves on the ExoLodges?
- Do different concrete material formulations affect marine biocolonisation?

*(ExoAnchor sinker, the jacket leg of K5PK, and the surrounding sand habitat)

4. Artificial reef design

The design of the "ExoLodge" artificial reef units is driven by the tender criteria of the Ijmuiden Ver tender. This outlines the need to increase suitable habitat for species native to the North Sea by deploying appropriately designed artificial reefs to sit within the scour protection of an offshore wind farm operation. Specific design criteria for the artificial reefs have been laid out, to optimise the habitat provision for native species, especially Atlantic cod (*Gadus morhua*) and Ross worm (*Sabellaria spinulosa*).

Each artificial reef unit has a weight of 4.5t with dimensions 1.8m x 1.7m x 1.7m.

It contains the following features:

- Large internal cylindrical pipe (min. diameter 1m).
- Slots and tunnels to allow water transfer.
- Holes to provide shelter habitats.
- Surface textures to facilitate biocolonisation.
- Addition of wood and metal features to support a range of communities (Rectangular wood and metal panels 17cm x 1.8m).
- Removable reef plugs for biodiversity monitoring of colonising species.

The design and measurements are detailed in Figure 1, Figure 2, Figure 3, Figure 4 and Figure 5.

Five ExoLodge units were manufactured using two different concrete-like material formulations. ExoLodge numbers 1, 2, and 3 were manufactured using concrete mix 1, and ExoLodge numbers 4 and 5 were manufactured using concrete mix 2. In addition, ExoLodge number 3 was coated in a lime solution prior to deployment.

Figure 1. Design renders of the ExoLodge

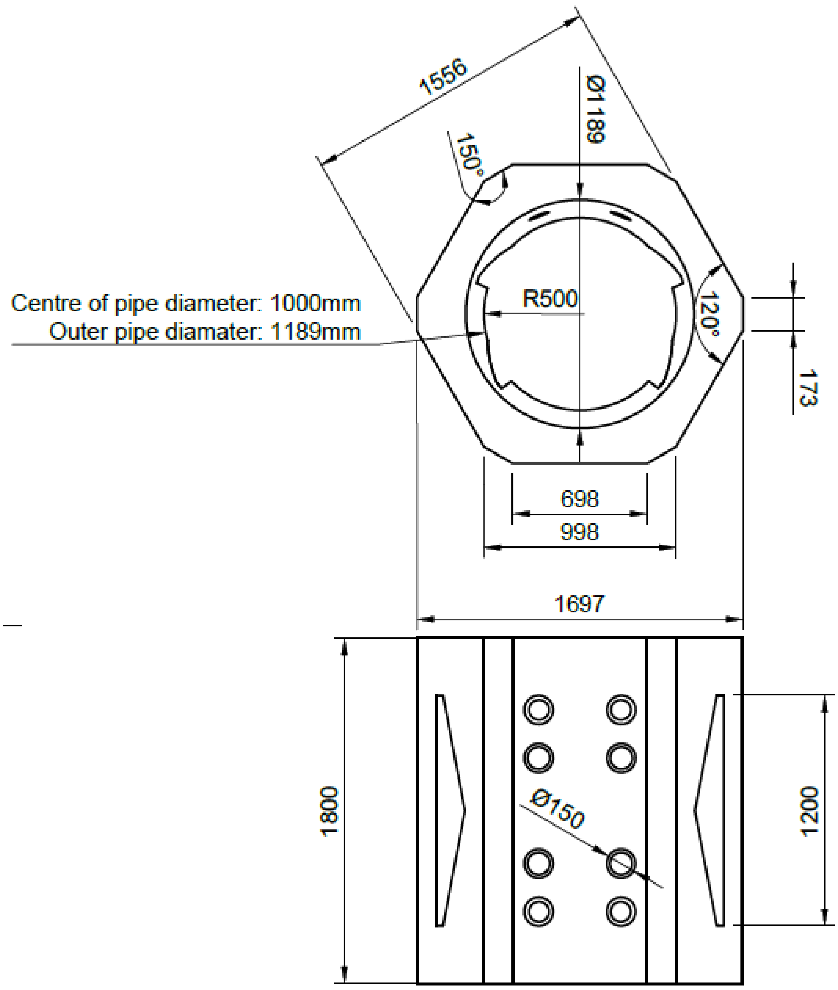

Figure 2. The ExoLodge design drawings with dimensions.

Figure 3. Close up of some of the ExoLodge wood and metal features and removable reef plugs

Figure 4. The five ExoLodges and the ExoAnchor control block prior to deployment.

Figure 5. The small concrete reef plug elements which sit atop the ExoLodges, including close-up of patterned design.

5. Site

The ExoLodge units were installed at the North Sea gas platform K5PK (53.696035°N, 3.3379069°E), which was first installed in 1992. The units were placed on a sandy seabed adjacent to one of the platform jacket legs. Deployment was completed around existing work scheduled at the platform on 28th July 2024 (Figure 6). The goal is to leave the artificial reefs in place for at least 5 years, possibly longer, to collect sufficient data over time.

Five ExoLodge units, and one ExoAnchor control unit were deployed by crane from the ship Northern Maria and positioned correctly on the seafloor using a work-class Remotely Operated Vehicle (ROV) with a manipulator arm. Reef unit number 1 was placed closest to platform jacket leg A2, then they run sequentially along the north face of the platform from east to west (Figure 7). Due to the overhang of the platform, the reef units were placed 2.5 – 3.5m from the mudline brace. Installation locations are detailed in Table 1.

Figure 6. Deployment of one of 5 ExoLodge units beside the North Sea gas platform K5PK on 28th July 2024.

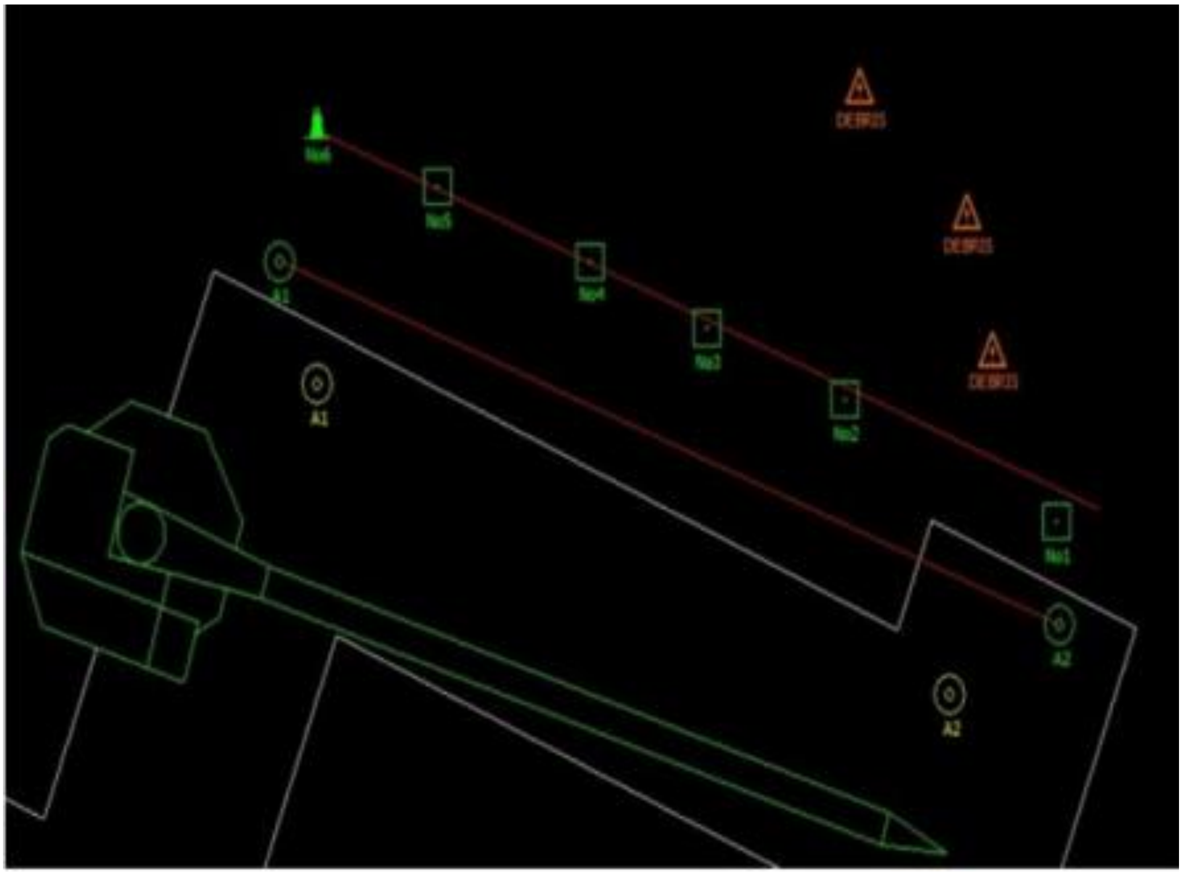

Figure 7. Deployment locations for the five ExoLodges (No. 1 – 5), and the ExoAnchor control unit (No. 6), in relation to the platform K5PK, represented by white lines..

Table 1. Location coordinates for the ExoLodge reef units and control unit (ExoAnchor) after positioning on the seafloor adjacent to platform K5PK.

Reef unit	Northing	Easting	Approx. distance from Brace
1	5341784	320328	2.5m
2	5341786	320322	3m
3	5341787	320318	3m
4	5341788	320215	3.5m
5	5341788	320310	3.5m
Control	5341789	320307	3.5m

In addition to monitoring the treatment site (ExoLodges), three control sites will also be monitored using the same protocols. These are:

- The base of the jacket leg on the opposite side of the platform to the installed reef units.
- 900kg ExoAnchor sinker, deployed alongside ExoLodge units (Figure 8).
- The surrounding sand habitat, devoid of hard infrastructure.

The control jacket leg has been present since initial installation in 1992, so the biodiversity associated with it will likely have already reached a climax community. However, at regular intervals during annual maintenance of the platform, areas of the jacket legs are cleaned of all fouling organisms. This may allow for a comparison of the benthic fouling community on the ExoLodges with a relatively “clean” section of infrastructure, to assess concurrent colonisation.

The ExoAnchor sinker provides a reference structure deployed concurrently with the ExoLodges. They are constructed of a concrete material of a similar formulation to the ExoLodges but lack the range of additional nature-inclusive habitat features, such as holes, tunnels, and additional wood and metal features. Although some surface texturing is present, this is of a different design to texturing on the ExoLodges. Their deployment alongside the ExoLodges allows for the assessment of concurrent colonisation.

Additional environmental data related to the site are detailed in Table 2.

Table 2: Environmental parameters at the site (TotalEnergies platform K5PK)

Water depth at the site	40 m
Current speed at max depth	1 m/s but depending on tide
Salinity	34.5 PSU
Dissolved oxygen at max depth	8.2 (mg l-1)
Turbidity at max depth	5.5 NTU
Substrate type	Fine to medium sand

Figure 8. ExoAnchor sinker, deployed alongside the ExoLodge units as a control site.

6. Biodiversity Monitoring

To capture the full range of biodiversity associated with the installed units, several different methods will be used. Monitoring of the artificial reef units at K5PK will take place every year during the annual ROV campaign of TotalEnergies EP Nederland. Monitoring will use the following techniques: eDNA analysis from waters (including laboratory analysis of samples), ROV footage (video and still photographs), taxonomic identification of species on recovered reef plugs.

Some monitoring methods will be more appropriate for capturing certain biodiversity, such as either sessile species (e.g. algae and attaching invertebrates), or mobile species (e.g. fish and crustaceans). By combining these methods, we will better understand the full impact of the units and the associated biodiversity gain.

6.1 Monitoring Schedule

Biodiversity monitoring will be undertaken during annual ROV maintenance campaigns, following the schedule detailed in Table 3 below. Following baseline surveys alongside deployment in July 2024, the first monitoring campaign be undertaken in the summer/autumn of 2025. This will then be followed by subsequent monitoring campaigns repeated annually.

Table 3. Monitoring schedule for deployed artificial reef units and control sites.

Date	ROV video surveys and photographs	eDNA water sampling	Reef plug visual analysis
Deployment July 2024	✓	✓	
Summer/Autumn 2025	✓	✓	✓
Summer/Autumn 2026	✓	✓	✓
Summer/Autumn 2027	✓	✓	✓
Summer/Autumn 2028	✓	✓	✓
Recurring annually	✓	✓	✓

6.2 Baseline Monitoring

To provide a baseline assessment of the biodiversity currently present at the site at Time Zero (T0), two monitoring methods were used at the site, analysis of ROV video footage and laboratory analysis of environmental DNA (eDNA) from water samples.

6.3 ROV video surveys

6.3.1 Methods

Alongside deployment of the ExoLodges at the site on 28th July 2024, high-definition video surveys were undertaken using TotalEnergies' work-class ROV, fitted with a high-definition camera. Surveys of two sites were undertaken, the platform jacket leg, and the surrounding seabed, to ascertain the variety of marine species using the different habitats present.

For this monitoring period, a 15-minute roving survey of the platform jacket leg was undertaken, along with two surveys of the surrounding sandy-bottomed seabed, one of 23-minute duration and one of 17-minute duration, using set transect routes. During the seabed survey the ROV landed on the seabed at a regular interval to record the mobile species. All the high-definition footage and stills were taken with timestamps and location information attached, and flightpaths were recorded so that they can be followed in future years during the annual monitoring campaign.

6.3.2 Methods of Analysis

All ROV videos were provided to The Rich North Sea for analysis. They were categorized as 'Sand' or 'Jacket' habitats. Per habitat type, species that could be recognized (>2 cm) were noted during inspection of the video footage. Taxonomic groups recorded included epifauna, mobile invertebrates, and fish species, and identification was done to the lowest taxonomic level possible, mostly species.

Along with presence, an indication of abundance was given to the taxa using the scale that the ANEMOON foundation uses for divers that perform citizen science for the MOO-project (Monitoringproject Onderwater Oever) in the Netherlands. In this case, only the classifications of 'Z' = 'Rare' ('Zeldzaam', 1-9 individuals/colonies), 'A' = 'Common' ('Algemeen', 10-99 individuals/colonies) and 'M' = 'Abundant' ('Massaal', >100 individuals/colonies) were used.

6.3.3 Results

A total of 23 species were recorded at the platform jacket leg and surrounding sandy seabed, listed in Table 4. At each habitat surveyed, 13 species were identified. One fish species, Pouting (*Trisopterus luscus*), was recorded in both habitats, as were European lobsters (*Homarus Gammarus*) and Plumose anemones (*Metridium senile*). 8 additional fish species were recorded on the sand, of which Common dragonet (*Callionymus lyra*), Common dab (*Limanda limanda*), and Atlantic horse mackerel (*Trachurus trachurus*) were the most abundant, along with pouting.

On the jacket, Velvet swimming crabs (*Necora puber*) were also abundant. A community of sessile, attaching organisms was present, made up of various sponges, barnacles, bryozoans, ascidians, and cnidarians. These included 3 anemone species, of which the Orange anemone (*Diadumene cincta*) and the Plumose anemone were most abundant, and the soft coral Dead man's fingers (*Alcyonium digitatum*) was also common.

Table 4. List of species recorded from ROV surveys at the platform jacket leg and surrounding sand habitat in July 2024. Abundance scores follow MOO-project classifications from the ANEMOON Foundation, Netherlands.

Taxomonic group	Scientific name	English common name	Sand	Jacket
Fish	*Callionymus lyra*	Common dragonet	A	
	Eutrigla gurnardus	Grey gurnard	Z	
	Limanda limanda	Common dab	A	
	Merlangius merlangius	Whiting	Z	
	Microstomus kitt	Lemon sole	Z	
	Mullus surmuletus	Striped red mullet	Z	
	Pomatoschistus sp.	Goby sp.	Z	
	Trachurus trachurus	Atlantic horse mackerel	A	
	Trisopterus luscus	Pouting	A	A
Crustaceans	*Homarus gammarus*	European lobster	Z	Z
	Necora puber	Velvet swimming crab		A
	Cancer pagurus	Edible crab		Z
	Balanus balanus	Rough barnacle		A
Annelids	*Annelida*	Annelid worm sp.	Z	
Echinoderms	*Astropecten irregularis*	Sand star	Z	
Cnidarians	*Metridium senile*	Plumose anemone	A	M
	Cylista elegans	Elegant sea anemone		A
	Diadumene cincta	Orange anemone		M
	Alcyonium digitatum	Dead man's fingers		A
Sponges	*Mycale micracanthoxea*	*Mycale micracanthoxea* sponge		Z
	Porifera	Sponge sp.		Z
Bryozoans	*Bryozoa*	Bryozoan sp.		A
Ascidians	*Diplosoma listerianum*	*Diplosoma listerianum* compound sea squirt		A

Z' = 1-9 individuals/colonies; '**A**' = 10-99 individuals/colonies; '**M**' = >100 individuals/colonies

6.4 eDNA analysis of water samples

On 8th August 2024, 11 days after deployment of the ExoLodge artificial reef units at the site, water samples were collected from depth at three sampling locations within the vicinity of Platform K5PK in the Dutch North Sea. Following their collection, the water samples were filtered, and the genetic material captured was sent for laboratory analysis.

6.4.1 Methods

Three sampling locations were chosen at the site, the target site at K5PK, where the artificial reef units have been deployed (Location 1), 350-500m downstream (Location 2), 350-500m upstream (Location 3) (Table 5, Figure 9). Samples were collected on 8th August 2024 between 08:30 – 12:30. Samples were collected around slack water at high tide on that morning, which ensured the least water movement when collecting the samples.

The prevailing bottom current direction at the site is SSW to NNE, which determined the specific locations chosen for water sample collection. Water samples for the target location were 86m north of the ExoLodges, which ensured that the water collected had first passed through the platform and artificial reef site. The downstream samples collected from Location 2 were likely to have picked up water from the platform, as well as the surrounding area, whereas the upstream samples (Location 3) can be treated as independent controls, as water collected from this location will not have passed through the platform or artificial reef site. 400-500m distance is considered far enough away from the target site to not be influenced by the platform.

Table 5. Location coordinates for water sampling for eDNA analysis.

Sampling location	Approx. distance from artificial reefs (m)	Coordinates (Lat, Long, DMM)	Current Direction/ Speed (Surface/Bottom)	Depth (m)
1: K5PK (target site)	86m North	53°41.834 'N 003°20.320 'E	260° / 1.4 kts 065° / 0.7 kts	40 m
2: Downstream	350m North	53°41.961 'N 003°20.406 'E	264° / 1.6 kts 065° / 0.7 kts	41 m
3: Upstream	425m South	53°41.522 'N 003°20.133 'E	160° / 1.1 kts 025° / 0.6 kts	39 m

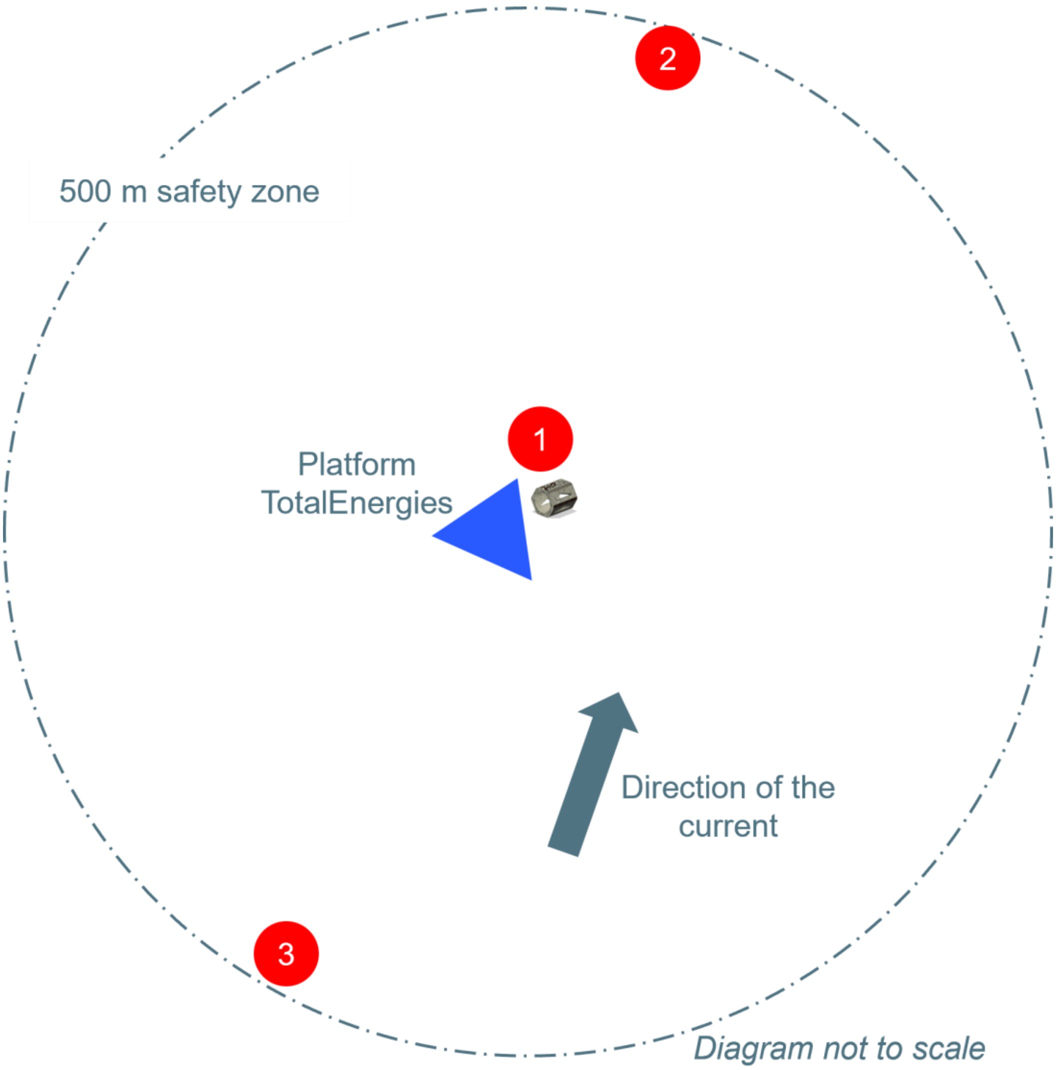

Figure 9. Diagram visualising the sampling locations for eDNA water sampling at platform K5PK in the Dutch North Sea.

Water samples were collected from a vessel at the site using a Niskin bottle (Figure 10) from the port side of the vessel Bibby Wavemaster 1. The 5 litre Niskin bottle was attached to a steel cable with 5kg lead weights hanging from the bottom. The bottle was lowered to the bottom, then lifted up by approximately 1.5m. A messenger was then sent down the cable to close the valves. Three water samples were collected from each sample location, which were filtered on board the vessel, using a setup which included an Erlenmeyer flask, tube, filter paper, magnetic cup, overflow bottle, and pump (Figure 11). The filter was then removed and placed in a 2ml screwcap tube, prefilled with 400ul Zymo DNA/RNA shield preservation solution. Nine eDNA samples were collected, and a tenth water sample was filtered as a blank using fresh water.

Fresh latex/nitrile gloves were worn for each sample collected, and all sampling equipment was disinfected with a 1% chlorine solution between sample collection, then rinsed with fresh water.

Once collected and filtered, all samples were stored in the freezer. The frozen samples were sent for laboratory analysis of the eDNA present at Eurofins once the vessel returned to dock.

Figure 10. Niskin bottle used for water sample collection for eDNA

Figure 11. Water filtration kit used to filter eDNA from seawater samples.

6.4.2 Results

The vertebrate and invertebrate taxa recorded from eDNA analysis of the water samples collected at each sampling location are listed in Table 6 and Table 7 below.

Table 6. Vertebrates recorded from eDNA analysis of water samples collected at K5PK, the artificial reef deployment location (Site 1), the downstream location (Site 2), and the upstream location (Site 3).

Taxa	Higher taxon	Common name	Site 1 K5PK	Site 2	Site 3
Gadiformes;Gadidae	Codfish (Gadids)		✓	✓	✓
Clupeiformes;Clupeidae;Sprattus;Sprattus sprattus		Sprat		✓	✓
Carangiformes;Carangidae;Trachurus;Trachurus trachurus		Atlantic horse mackerel	✓	✓	✓
Carangiformes;Carangidae;Trachurus	Jack mackerels		✓	✓	✓
Pleuronectiformes;Bothidae;Arnoglossus;Arnoglossus laterna		Mediterranean scaldfish	✓	✓	✓
Pleuronectiformes;Pleuronectidae;Limanda	Righteye flounders		✓	✓	✓
Clupeiformes;Clupeidae	Herrings				✓
Artiodactyla;Phocoenidae;Phocoena;Phocoena phocoena		Harbour porpoise	✓	✓	✓
Pleuronectiformes;Pleuronectidae;Pleuronectes	Righteye flounders		✓	✓	✓
Pleuronectiformes;Pleuronectidae	Righteye flounders		✓	✓	✓
Perciformes;Trachinidae;Echiichthys;Echiichthys vipera		Lesser weever	✓	✓	
Gadiformes;Gadidae;Trisopterus;Trisopterus minutus		Poor cod	✓		
Scombriformes;Scombridae;Scomber;Scomber scombrus		Atlantic mackerel		✓	✓
Clupeiformes;Clupeidae;Clupea;Clupea harengus		Atlantic herring			✓
Clupeiformes;Clupeidae;Clupea;Clupea pallasii		Pacific herring			✓
Gadiformes;Gaidropsaridae;Enchelyopus;Enchelyopus cimbrius		Fourbeard rockling			✓
Pleuronectiformes;Soleidae;Buglossidium;Buglossidium luteum		Solenette		✓	✓
Clupeiformes;Engraulidae;Engraulis;Engraulis encrasicolus		European anchovy		✓	
Carcharhiniformes;Scyliorhinidae;Scyliorhinus;Scyliorhinus canicula		Small-spotted catshark			✓
Gobiiformes;Gobiidae;Pomatoschistus;Pomatoschistus minutus		Sand goby	✓		
Gobiiformes;Gobiidae;Aphia;Aphia minuta		Transparent goby			✓
Total species richness per site			**11**	**13**	17

Table 7. Invertebrates recorded from eDNA analysis of water samples collected at K5PK, the artificial reef deployment location (Site 1), the downstream location (Site 2), and the upstream location (Site 3).

Taxa	Higher taxon	Common name	Site 1 K5PK	Site 2	Site 3
Arthropoda;Hexanauplia;Calanoida;Paracalanidae;Paracalanus;Paracalanus parvus	Copepod		✓	✓	✓
Arthropoda;Hexanauplia;Cyclopoida;Oithonidae;Oithona;Oithona similis	Copepod		✓	✓	✓
Annelida;Polychaeta;Terebellida;Pectinariidae;Pectinaria;Pectinaria koreni	Bristleworm			✓	✓
Cnidaria;Scyphozoa;Semaeostomeae;Pelagiidae;Chrysaora;Chrysaora hysoscella	Jellyfish	Compass jellyfish	✓		✓
Annelida;Polychaeta;NA;Capitellidae;Capitella;Capitella sp.	Bristleworm		✓	✓	
Arthropoda;Hexanauplia;Calanoida;Clausocalanidae;Pseudocalanus;Pseudocalanus elongatus	Copepod		✓	✓	✓
Mollusca;Bivalvia;Myida;Corbulidae;Varicorbula;Varicorbula gibba	Bivalve	Basket shell	✓	✓	✓
Arthropoda;Hexanauplia;Harpacticoida;Miraciidae;Haloschizopera;Haloschizopera pygmaea	Copepod		✓	✓	✓
Annelida;Polychaeta;Sabellida;Sabellariidae;Sabellaria;Sabellaria spinulosa	Bristleworm	**Ross worm**		✓	
Annelida;Polychaeta;Spionida;Spionidae;Spiophanes;Spiophanes cf. bombyx	Bristleworm				✓
Arthropoda;Hexanauplia;Calanoida;Temoridae;Temora;Temora longicornis	Copepod		✓	✓	✓
Arthropoda;Hexanauplia;Harpacticoida;Euterpinidae;Euterpina;Euterpina acutifrons	Copepod		✓	✓	✓
Annelida;Polychaeta;NA;Protodrilidae;Protodrilus;Protodrilus adhaerens	Bristleworm				✓
Arthropoda;Hexanauplia;Poecilostomatoida;Corycaeidae;Ditrichocorycaeus;Ditrichocorycaeus anglicus	Copepod		✓	✓	✓
Annelida;Polychaeta;Phyllodocida;Sigalionidae;Sthenelais;Sthenelais limicola	Bristleworm				✓
Arthropoda;Hexanauplia;Calanoida;Centropagidae;Isias;Isias clavipes	Copepod		✓		
Cnidaria;Hydrozoa;Anthoathecata;Pandeidae;Leuckartiara;Leuckartiara octona	Jellyfish		✓		✓
Cnidaria;Hydrozoa;Leptothecata;Aequoreidae;Aequorea;Aequorea vitrina	Jellyfish	Crystal jellyfish	✓		
Arthropoda;Hexanauplia;Polyarthra;Longipediidae;Longipedia;Longipedia sp.	Copepod			✓	
Arthropoda;Hexanauplia;Calanoida;Acartiidae;Acartia;Acartia clausii	Copepod			✓	
Mollusca;Bivalvia;Cardiida;Semelidae;Abra;Abra nitida	Bivalve	Glossy furrow shell		✓	
Cnidaria;Hydrozoa;Leptothecata;Clytiidae;Clytia	Jellyfish		✓	✓	✓
Annelida;Polychaeta;Terebellida;Pectinariidae;Pectinaria;Pectinaria auricoma	Bristleworm			✓	✓
Arthropoda;Hexanauplia;Harpacticoida;Idyanthidae;Tachidiella;Tachidiella minuta	Copepod			✓	

Mollusca;Bivalvia;NA;Thraciidae;Thracia;Thracia phaseolina	Bivalve			✓	
Arthropoda;Hexanauplia;Calanoida;Centropagidae;Centropages;Centropages hamatus	Copepod			✓	✓
Echinodermata;Echinoidea;Spatangoida;Loveniidae;Echinocardium;Echinocardium cordatum	Sea urchin	Sea potato			✓
Mollusca;Bivalvia;Cardiida;Semelidae;Abra;Abra alba	Bivalve	White furrow shell	✓		
Mollusca;Bivalvia;Venerida;Mactridae;Spisula;Spisula elliptica	Bivalve	Eliptical surf clam	✓		
Cnidaria;Hydrozoa;Leptothecata;Eirenidae;Helgicirrha;Helgicirrha cari	Jellyfish		✓	✓	✓
Arthropoda;Malacostraca;Decapoda;Polybiidae;Liocarcinus;Polybius depurator	Decapod crustaceans	Harbour swimming crab	✓	✓	✓
Cnidaria;Hydrozoa;Leptothecata	Jellyfish				✓
Cnidaria;Hydrozoa;Leptothecata;Campanulariidae;Eucheilota;Eucheilota maculata	Jellyfish				✓
Cnidaria;Hydrozoa;Siphonophorae;Agalmatidae;Nanomia;Nanomia cara	Siphonophore			✓	✓
Nemertea;Palaeonemertea;Archinemertea;Cephalotrichidae;Cephalothrix;Cephalothrix linearis	Ribbon worm				✓
Arthropoda;Malacostraca;Decapoda;Processidae;Processa;Processa nouveli	Shrimp		✓		
Rotifera;Eurotatoria;Ploima;Synchaetidae;Synchaeta;Synchaeta hutchingsi	Rotifer			✓	
Arthropoda;Arachnida;Sarcoptiformes;Pyroglyphidae;Dermatophagoides	Acariform mite			✓	
Cnidaria;Anthozoa;Malacalcyonacea;Alcyoniidae;Alcyonium	Soft coral	Dead man's fingers			✓
Echinodermata;Ophiuroidea;Amphilepidida;Amphiuridae;Amphiura;Amphiura filiformis	Brittlestar		✓		
Nemertea;Pilidiophora;Heteronemertea;Lineidae;Tenuilineus;Tenuilineus albocinctus	Ribbon worm			✓	
Total species richness per site			**20**	**25**	**25**

From eDNA samples analysed at the site, a total of 62 species were recorded overall, 21 vertebrate species and 41 invertebrate species. A total of 31 species were recorded from water samples collected closest to the artificial reef deployment location, 11 of these were vertebrates (fish and marine mammals) and 20 were invertebrates. For the samples collected 500m downstream (site 2), 38 species were recorded, 13 vertebrates and 25 invertebrates. For the upstream samples (site 3), 42 species were recorded, 17 vertebrates and 25 invertebrates.

One marine mammal, the Harbour porpoise (*Phocoena Phocoena*) was recorded at all sites. Of the fish species recorded, Poor cod (*Trisopterus minutus*), and Sand gobies (*Pomatoschistus minutus*) were only recorded at the target site. Various fish species were only recorded from the upstream samples, which we can assume is relatively independent from the target location, due to its distance away from the site and the prevailing bottom current direction. These included Atlantic herring (*Clupea harengu*s), Pacific herring (*Clupea pallasii*), Fourbeard rockling (*Enchelyopus cimbrius*), Transparent goby (*Aphia minuta*), and Small-spotted catshark (*Scyliorhinus canicular*). The Small-spotted catshark's presence is of particular interest, as research was recently published into the use of offshore windfarms by elasmobranch species. In this study, from 436 water eDNA samples, the Small-spotted catshark was not detected[1]. Despite the species only being detected in the samples upstream of the platform, this is still only a short distance away from the offshore infrastructure.

Of the invertebrate species recorded, the majority from all samples were free-swimming copepod species (12 species), jellyfish species (7 species), and bristleworm species (7 species). Two bivalve species, White furrow shell (*Abra alba*) and Eliptical surf clam (*Spisula elliptica*), and a brittlestar species, *Amphiura filiformis*, were only recorded at the target site. Some species were only recorded in the upstream samples, including some worm species, Sea potatoes, and Dead man's fingers soft corals.

One of the target species, *Sabellaria spinulosa* (Ross worm) was detected in one of the samples collected downstream from the K5PK platform. This suggests that it may already be present at the platform, or the nearby area. As it was not detected from the samples closest to the deployment site, it may not currently be present close by to our deployed artificial reef units.

Regarding our second target species, Atlantic cod was not recorded, however, the broader codfish family, Gadidae was detected in all samples. This family also

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[1] Hermans, A., Sumner-Hempel, A., van den Brink, X., van Berkel, D., Olie, R.A., Winter, H.V., Murk, A. and Nijland, R., 2025. Elasmobranchs in offshore wind farms. *Ocean & Coastal Management*, *266*, p.107671. https://doi.org/10.1016/j.ocecoaman.2025.107671.

included species such as Poor cod, Pouting, Whiting, and Pollack, so this cannot be used to assume Atlantic cod is present at the site currently.

7. Discussion

ROV and eDNA surveys at the site have provided a comprehensive snapshot of the species present at the K5PK site and nearby habitats at the time of the artificial reef unit deployment. From the ROV surveys around the jacket leg and sand habitat near the base of the platform, the same number of species were recorded at both habitats. From eDNA surveys, marginally fewer species were recorded from water samples taken at the platform than the two sampling locations up- or down-stream.

Comparing the two monitoring methods, there are only a small number of species which overlap and were recorded at both sites. Atlantic horse mackerel (*Trachurus trachurus*) and Dead-man's fingers (*Alcyonium digitatum*) were the only species identified to species level that were recorded using both methods. Encompassing taxa identified to genus level, *Pomatoschistus* sp., *Limanda* sp., and *Trisopterus* sp. were also deteceted from both methods.

Three sea anemone species were recorded from the ROV video analysis, whereas none were recorded from eDNA, and the sponges, bryozoans and ascidians recorded from ROV video analysis were also not detected from eDNA. A greater number of decapod crustacean species were also recorded using the visual analysis of ROV footage, including European lobster, Velvet swimming crab, and Edible crab. From eDNA, only Harbour swimming crabs (*Polybius depurator*) were detected, which were not included in the species list from ROV video analysis. Two possible explanations for this could be that either there was a high presence of Harbour swimming crab larvae within the water column during eDNA water sampling, or that the preferred habitat of this species was on the sand only, so they would not have been detected on the platform structure itself.

Similarly, there were different fish species recorded using the two methods. Misidentification can be possible for Pouting (*Trisopterus luscus*) from the ROV footage, as Poor cod (*Trisopterus minutus*) was detected using eDNA methods, and the two species are very similar morphologically. However, the majority of the species recorded from the video analysis were confirmed as *T. luscus* with high confidence. Flatfish species can also be difficult to accurately identify from video footage alone, so misidentification is also possible for these species. However, several other species were only detected using one method or the other, including many for which misidentification can be completely ruled out, so it is very likely their DNA was simply not collected in the water samples.

Additionally, Dead man's fingers soft corals (*Alcyonium sp.*) were identified visually on the platform jacket leg from the ROV footage, while this species was only recorded from the upstream eDNA samples. Looking at the eDNA data alone, we could mistakenly suggest that this species was not present on the jacket. However, analysis of the ROV footage has shown this assumption to be incorrect. From work undertaken on other projects, we have found that species detected from video surveys are often not recorded in eDNA surveys from the same area. This shows the benefits of using complementary methods such as these, with the inclusion of visual analysis of ROV footage also providing more definite confirmation of these species' presence at the specific habitat locations being surveyed.

The addition of eDNA monitoring does provide several benefits. Firstly, using this method enabled the detection of several more elusive fish species that may have otherwise been scared by the presence of the ROV, including the noise of their thrusters and the lights used. Greater taxonomic resolution also becomes possible within groups that are difficult to identify from video analysis alone, such as annelid worms. Additionally, the eDNA surveys detected a wide range of small to microscopic species as well, including copepods, worms, jellyfish, and bivalves, which made up the vast majority of the 41 invertebrate species detected using this method.

8. Conclusion

The use of two complementary methods to provide a broad baseline biodiversity profile of the site has proved successful, with a total of 83 taxa recorded overall, excluding those recorded to species level by both methods. Most species were only recorded using one method or the other. Several were recorded using visual analysis of ROV footage collected which were not detected from eDNA analysis of water samples collected, and a large number of additional species present in the water column were detected by including eDNA analysis. This included many smaller or microscopic species which would be near impossible to detect otherwise, but also as some larger, more charismatic species which may be unlikely to be recorded during short video surveys of these habitat types, or would otherwise be deterred by the presence of the ROV, such as the Harbour porpoise.

These surveys will be repeated annually to assess changes over time, as well as comparing this to the species associated with the deployed artificial reefs. Comparisons of this data with control sites over time will allow us to assess the additional biodiversity benefits gained from the installation of these artificial reef units at the site.

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