
Environmental Impact Assessment Report
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# MarramWind Offshore Wind Farm

December 2025

MarramWind

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MarramWind Ltd.

# MarramWind Intertidal Macrobiota Survey 2023

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| 2.1 | 20/12/2023 | 2.6.1<br>3.6 | 15<br>36 | Data analysis methods updated to include cluster analysis. Results of cluster analysis added. | SP, CA |
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## Executive Summary

MarramWind is a floating Offshore Wind Farm (OWF) being developed by MarramWind Limited, a company wholly owned by ScottishPower Renewables UK Limited (SPR). MarramWind OWF will be located in the north-east Scotland about 100 km off Fraserburgh. The location of this OWF is ultimately determined by the Option Area Agreement (OAA) which is the spatial boundary of the NE7 Plan Option in which the electricity generating infrastructure will be located.

The planned export cable route extends south-west towards the coast and splits into three cable route landfall zone options: Landfall D (Scotstown Beach), Landfall E (Lunderton Beach) and Landfall F (Sandford Bay). APEM was commissioned to undertake surveys of intertidal habitats and biological communities in the vicinity of each of the three zones. This report summarises the findings of these surveys and the subsequent laboratory analysis.

The landfall zones were surveyed between 16th and 19th July 2023, with each zone surveyed on a separate day, but Landfall F being surveyed across two survey days. Intertidal biotopes were mapped and photographed. Upper, mid, and lower shore 0.01 $m^2$ sediment core samples (1 for biota, 1 for PSA) were collected along transects placed at 500 m intervals along each area (4 transects at Landfall D and Landfall E; 3 at Landfall F). Two additional samples were collected at Landfall E. Macrobiota samples were photographed and sieved at 0.5 mm at the laboratory. Contaminant analysis samples (reported in APEM, 2023) were also collected. At two Landfall F transects, quarry stones meant that cores could not be used and 0.25 $m^2$ quadrats were used to record conspicuous biota.

Most of the shore at Landfall D and Landfall E and the central area at Landfall F was intertidal sand. The upper shore was colonised by talitrid amphipods (sandhoppers: *Talitrus saltator*) and enchytraeid oligochaetes with most samples assigned to the biotope LS.LSa.St.Tal (Talitrids on the upper shore and strand-line). Mid- and lower shore sediments were inhabited by polychaete worms (mainly *Scolelepis squamata*) and Crustacea (mainly *Pontocrates arenarius* and *Bathyporeia* spp.) were mostly assigned to LS.LSa.MoSa.AmSco.Pon (*Pontocrates arenarius* in Atlantic littoral mobile sand) or related sub-biotopes. There were scattered areas of more impoverished sand biotopes. At the southern end of Landfall D, the northern and southern extremities of Landfall E and over wide areas on the northern and southern shores of Landfall F, a range of hard substratum biotopes was recorded, including upper shore lichen zones, fucoid zonation, scoured rock biotopes and barnacle dominated biotopes.

No Annex I habitats, Priority Marine Features (PMF), or OSPAR threatened and/or declining species were recorded during the survey. The mobile sand habitat species are adapted to sediment movement and are able to recover quickly from disturbance. The lower shore *Fucus serratus* on eulittoral boulders biotope correlates with the intertidal boulder habitat

listed in the Scottish Biodiversity List (SBL). Some of the hard substrata areas included rockpools and underboulder communities and may constitute SBL priority habitat. No Invasive and Non-Native Species (INNS) were observed during the survey or recorded from the samples.

# 1. Introduction

APEM was commissioned by MarramWind Limited, a company wholly owned by ScottishPower Renewables UK Limited (SPR), to design and undertake a survey of intertidal habitats and biological communities in the vicinity of three MarramWind Export Cable Corridor landfall locations.

The offshore wind farm area is situated about 100 km off Fraserburgh, north-east Scotland (Figure 1). The area was surveyed in 2022, including geophysical, environment and shallow geotechnical surveys. The planned cable route extends south-west from the wind farm area towards the coast and the export cable corridor site investigation (ECC SI) campaign, which includes environmental, geophysical and shallow geotechnical survey works along the route, is to be completed before the end of 2023.

The cable route splits into three potential export route options about 30 km before landfall. The three potential landfall zones currently being considered have been designated as Option D (Scotstown Beach), E (Lunderton Beach) and F (Sandford Bay) (Figure 1). Intertidal surveys were required at the landfall of each of the three landfall options.

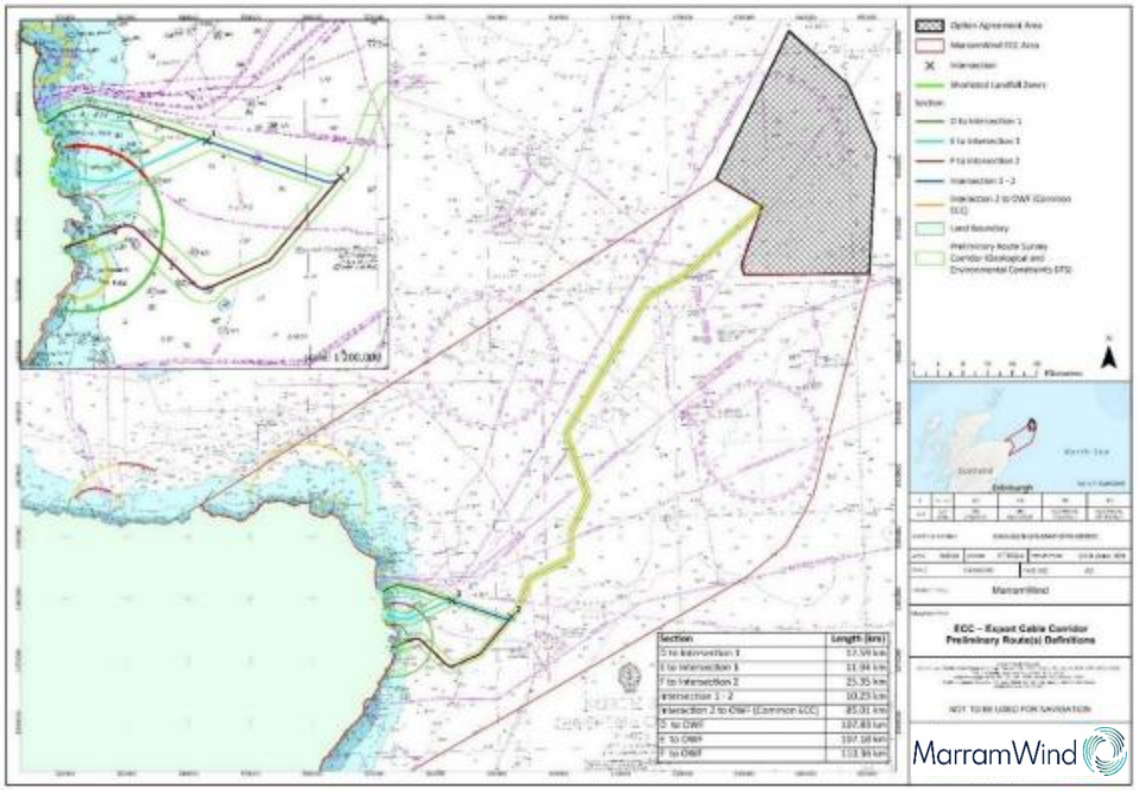


**Figure 1. Map showing location of the Marram Wind proposed wind farm area and possible cable route options (image from the scope of work provided with the tender invitation)**

### 1.1 Survey Objectives

The objective of the work commissioned was to design and undertake surveys to obtain benthic macrobiota site characterisation for EIA purposes. The following approaches were used:

- Macrobiota surveys (biotope maps, core samples and quadrats);
- Particle size analysis (PSA).

This report presents the methodologies adopted by APEM for the collection, processing, and analysis of the survey data, followed by a presentation of the survey data and summary of the findings from the survey.

## 2. Methodology

### 2.1 Survey Permissions

Some consents or notifications were required prior to the survey; however, all parking and access to the sites were public access. The permissions included:

- Notice of intention to carry out an Exempted Activity
- Crown Estate (General Marine Works License or equivalent)
- Other voluntary or statutory notifications

### 2.2 Survey Timings

Landfall D was surveyed on 18th July 2023. Landfall E was surveyed on 17th July 2023. Landfall F was surveyed on 16th and 19th July 2023. Table 1 (below) shows tidal information for each survey day and location.

**Table 1 Tidal information for each landfall zone on the survey dates**

| Location | Landfall F | Landfall E | Landfall D | Landfall F |
|---|---|---|---|---|
| **Date** | Sun 16th July 2023 | Mon 17th July 2023 | Tue 18th July 2023 | Wed 19th July 2023 |
| **Hight tide**<br>**Height** | 12:49<br>3.4 m | 01:12<br>3.47 m | 01:50<br>3.53 m | 02:34<br>3.74 m |
| **Low tide**<br>**Height** | 06:41<br>1.00 m | 07:25<br>1.1 m | 08:03<br>1.03 m | 08:43<br>0.89 m |
| **High tide**<br>**Height** | 13:13<br>3.4 m | 13:42<br>3.37 m | 14:21<br>3.4 m | 15:07<br>3.54 m |
| **Low tide**<br>**Height** | 18:59<br>1.1 m | 19:34<br>1.29 m | 20:08<br>1.26 m | 20:48<br>1.24 m |
| **Sunrise**<br>**Sunset**<br>**Daylight length** | 04:33<br>21:51<br>17:18 hours | 04:35<br>21:49<br>17:13 hours | 04:37<br>21:48<br>17:10 hours | 04:39<br>21:46<br>17:07 hours |

## 2.3 Health and Safety

A Risk Assessment was carried out prior to the survey work. In addition, daily dynamic risk assessments were completed by the lead surveyor (Georgina Brackenreed-Johnston) to address any site-specific issues. Primary health and safety concerns were becoming trapped by incoming tides and exposure risks. All staff wore appropriate Personal Protective Equipment (PPE) for survey work, including life jackets, and waterproofs, to minimise exposure risks; the team carried a field first aid kit and throw rope. All staff were provided with emergency contact numbers, the entry and exit points to the beach, tidal information for the survey zones and the times of sunrise and sunset for each day; these were carried at all times. Check-in and out calls were made to office-based staff at previously agreed times, coinciding with expected times accessing and leaving the shore.

## 2.4 Survey Design

Intertidal surveys were completed at each of the three proposed cable landfall zones, to include both hard and soft substrata. Any designated features of nearby Marine Protected Areas (MPAs) or other designated sites were noted. The surveys comprised Phase I habitat mapping, together with quantitative Phase II core or quadrat sampling at representative habitats for macrobenthic communities, Particle Size analysis (PSA) and contaminants samples (discussed in APEM, 2023). Transects were surveyed covering upper, mid, and lower shore zones at 500 m intervals across each landfall zone (Figure 2). Landfall zones D and E were each 2 km long in horizontal extent, so included four vertical transects. Landfall F was approximately 1.16 km long and included three vertical transects. Two more stations were selected, where potential additional biotopes were noted at Landfall E. However, the

lower shore could not be reached, except at Transects 1 and 2 at Landfall D. All landfall zones were photographed. Descriptions were made of each zone and its characteristics. Details of each of the three Phase I survey areas and the Phase II samples collected and recorded from each are shown in Figure 3 for Landfall D, Figure 4 for Landfall E and Figure 5 for Landfall F.


**Figure 2. Map showing location of intertidal phase I and II survey locations at each landfall zone**


**Figure 3. Map showing Landfall D intertidal phase I and II survey locations**


**Figure 4. Map showing Landfall E intertidal phase I and II survey locations**


**Figure 5. Map showing Landfall F intertidal phase I and II survey locations**

A summary of samples collected is presented in Table 2, below and details of sampling positions, dates and times are presented in Appendix 1 Sampling stations were prefixed D, E and F, to represent each landfall zone, followed by 1, 2, 3 or 4, to represent transect numbers, and by U, M or L, for upper, mid, or lower shore. Original sample designations are included in Appendix 1.

**Table 2. Sample types collected at each landfall zone, with codes.**

c: 0.01 $m^2$ Core; q: 0.25 $m^2$ quadrat.

| | Landfall D | | | | Landfall E | | | | | Landfall F | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Transect number / Shore positions | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | Additional | 1 | 2 | 3 |
| Upper shore | D1U (c) | D2U (c) | D3U (c) | D4U (c) | E1U (c) | E2U (c) | E3U (c) | E4U (c) | WP91 (c) WP121 (c) | F1U (c) | F2U (q) | F3U (q) |
| Mid shore | D1M (c) | D2M (c) | D3M (c) | D4M (c) | E1M (c) | E2M (c) | E3M (c) | E4M (c) | – | F1M (c) | F2M (q) | F3M (q) |
| Lower Shore | D1L (c) | D2L (c) | D3L (c) | D4L (c) | E1L (c) | E2L (c) | E3L (c) | E4L (c) | – | F1L (c) | F2L (q) | F3L (q) |

All samples were clearly labelled both internally and externally with the following information:

- Project number and title;
- Sample identifier code;
- Date and time of sampling.

### *2.4.1 Intertidal Phase I survey*

Intertidal Phase I surveys were conducted across the entire area of each of the three potential landfall zones to determine biotope composition, biotope distribution, extent of sub-features and notable biotopes, with the aim of achieving 100% coverage of each shore. This included any features of conservation importance including Annex I habitats, Priority Marine Features, and notable species within the landfall zone.

All soft and hard substrates within the proposed landfall zones were surveyed during the Phase I survey. Biotope data for each biotope at each landfall were recorded on Marine Nature Conservation Review (MNCR) record forms.

A walkover survey was conducted in accordance with best practice guidance, including the JNCC Marine Monitoring Handbook Procedural Guideline (Davies *et al*., 2001), Wyn *et al*. (2006), JNCC (2010), Saunders *et al*. (2011), Nobel-James *et al*. (2018), and NRW (2019). A hand-held GPS system was carried throughout the survey to accurately plot waypoints of the features and delineate biotope boundaries to inform subsequent mapping. Intertidal biotopes were identified and characterised following the Marine Habitat Classification system for Ireland and Britain (Connor *et al*., 2004), with reference to Parry (2015) and updated to the EUNIS classification system (2012 and 2022 code systems included).

For each habitat/biotope surveyors recorded:

- Notes relating to the biotic assemblage including key taxa present;
- Substratum type;
- Wave exposure;
- Shore type;
- Presence of rockpools;
- Anthropogenic pressures; and
- Key features of interest.

Photographs were taken of each habitat or feature of interest and any important survey findings, e.g. findings which could affect the routing or require development of specific mitigation measures, were reported to the project team informally as soon as possible following the survey.

### *2.4.2 Sediment Core Sampling*

Intertidal core samples were collected at three stations (one upper shore, one mid shore and one lower shore) on each transect at each of the proposed landfall zones. At each station two sediment core samples were collected (one for analysis and the second as a spare to be stored). Two additional samples were collected to characterise biotopes (anoxic sand and *Arenicola* casts) noted in the field at Landfall E. Samples were collected using a 0.01 $m^2$ hand-held core pushed into the sediment to a depth of 15 cm (Dalkin & Barnett, 2001), also considering UKTAG Water Framework Directive (WFD) guidance (WFD-UKTAG, 2014). An additional 15 cm depth of sediment was dug below each core as a search for larger, deeper burrowing animals. Each sample was photographed, and the physical characteristics described (e.g. notable fauna or the depth of any anoxic layer). The biological samples were sieved over a standard 0.5 mm mesh, preserved in 4% formaldehyde solution, and stored in a suitable container.

An additional sample was acquired for particle size analysis (PSA) and another for contaminants analysis (Heavy Metals, Polycyclic Aromatic Hydrocarbons (PAHs), Polychlorinated Biphenyls (PCBs), Total Organic Carbon (TOC), Total Petroleum

Hydrocarbons (TPH) and Organotins (specifically, tributyltin (TBT) and dibutyltin (DBT)); contaminant analyses are reported elsewhere (APEM, 2023). The PSA and chemical samples were stored in suitable containers and frozen as soon after collection as practicable.

All samples were clearly labelled both internally and externally with a minimum of the following information:

- Contract and work order numbers;
- Reference of the sample area and site;
- Date and time of sampling.

Following the collection of each macrobiota core sample, the area below the core was excavated to a depth of approximatively 20 to 30 cm and examined in the field for larger macrofaunal species which may have been missed in the core samples.

In areas of hard substrata, core sampling was not possible and alternative sampling strategies, using quadrats, were required.

### *2.4.3 Quadrat sampling*

Quadrats were required at Landfall F on Transects 2 and 3, across the whole shore (three stations on each transect). Standard 0.25 $m^2$ quadrats, were used to record biota at the stations where quarry stones had been placed. One quadrat was placed at each of these stations. Conspicuous animals were counted; non-countable biota was recorded as percentage cover.

## 2.5 Sample analysis

All samples collected during the survey were transported to APEM's Letchworth laboratory, where biological samples were analysed. Particle size samples were transported to a third-party laboratory (Kenneth Pye and Associates Ltd. (KPAL)) for analysis.

### *2.5.1 Biological samples*

Biological samples were sieved over a standard 0.5 mm mesh and all biota extracted, in accordance with NMBAQC standard methodologies (Worsfold & Hall, 2010). Sub-sampling was not required for any core sample. Sediment residues were retained following internal QC and will be stored for 30 months, in formaldehyde solution.

Taxa were identified to the lowest practicable taxonomic level. Most were identified to species level but some taxonomic groups (e.g. insect larvae, nematodes, and certain oligochaetes) were identified to higher taxonomic levels according to widespread laboratory practices and the draft NMBAQC Scheme Taxonomic Discrimination Protocol (TDP), which

provides guidance on the most appropriate level to which different marine and brackish water taxa should be identified, as a routine. Appropriate taxonomic literature was used for identification, as listed in the NMBAQC Scheme's literature list (Worsfold et al., 2020), or sourced more recently. Where necessary, specimens were also compared with material maintained in APEM's laboratory reference collection.

Examples of the taxa recorded from the surveys were retained for inclusion in APEM's in-house reference collection. This collection acts as a permanent record of the biota recorded from each project and can be revisited at later dates should new evidence (e.g. descriptions of a new, closely related species) call an original identification into question.

Taxonomic nomenclature follows the World Register of Marine Species (WoRMS Editorial Board, 2023), except where more recent revisions are known to supersede WoRMS. The species directory code (Howson & Picton, 1997) was added where appropriate. Notable taxa recorded from the survey, such as rare or protected species, non-native taxa, or potentially un-described species, were highlighted.

### *2.5.2 Particle size analysis (PSA)*

Particle size analysis (PSA) was conducted to provide data on the sediment composition of the foreshore. Sediment composition has an effect on the biological species composition and how species interact with the sediments (e.g. burrowing activities or growth on coarser particles). Sediment grain size also has a significant impact on the absorption of chemical pollutants, with finer particles tending to have a higher pollution load index than coarse particles. In addition, fine sediments may be more easily transported away from their sources, thus expanding the potential for pollution impacts. However, fine sediments are also usually found in more stable environments where pollutants may be sequestered until remobilised by a disturbance event.

PSA was conducted following NMBAQC guidance (Mason, 2016), through a combination of sieve and laser analysis with wet separation at 2 mm. The <2 mm fraction was analysed through laser diffraction, whilst the >2 mm fraction was analysed through dry sieving. Summary statistics were calculated using GRADISTAT v8 (Blott & Pye, 2001) and reported at half-phi intervals providing the full particle size distribution, mean particle size, sorting coefficient, skewness, kurtosis, and modal size. Any cobbles were evaluated according to Cefas guidelines.

## 2.6 Data analysis and Reporting

### *2.6.1 Statistical analyses*

Following data collection and sample analysis, data matrices were produced to show abundances of each recorded taxon per sample. Basic data truncation was applied, to

combine data for different life stages of the same taxon. Univariate statistical analyses were undertaken using the PRIMER software package (Clarke & Warwick 2001; Clarke & Gorley, 2006; Clarke et al., 2014).

## Univariate Statistics

- Number of taxa (S);
- Abundance (number of individuals) per sample (N);
- Abundance (number of individuals) per $m^2$;
- Margalef's Species Richness (D): a measure of the number of species present for a given number of individuals;
- Pielou's Evenness (J'): represents the uniformity in distribution of individuals spread between species in a sample; high values indicate more evenness or more uniform distribution of individuals; the output range is from zero to one;
- Shannon Wiener Diversity H'($\log_e$): a widely used measure of diversity accounting for both the number of taxa present and the evenness of distribution of the taxa (Clarke & Gorley, 2006);
- Simpson Diversity (1-Λ): a dominance index derived from the probability of picking two individuals from a community at random that are from the same species; Simpson's dominance index ranges from zero to one with higher values representing a more diverse community without dominant taxa;

Non-countable taxa, such as colonial bryozoans and hydroids, were included when calculating total numbers of taxa, but excluded from calculations of total numbers of individuals and other diversity indices. Abundances were also standardised to numbers per $m^2$ and averaged for each taxon for each quantitative sample type.

## Multivariate Statistics

Hierarchical clustering was carried out on a Bray-Curtis similarity matrix of the macrobenthic abundance data in order to visualise the biological similarity between samples. The hierarchical clustering technique compares the abundance of each taxon in each sample, with its abundance in each of the other samples. The result is a matrix of pairwise similarity indices comparing each sample with all other samples. This similarity matrix is presented diagrammatically as a dendrogram. The similarity profile (SIMPROF) test was carried out as part of the clustering routine. This permutational test distinguishes clusters of samples that cannot be statistically differentiated at the 5% significance level and identifies them on the resulting dendrogram using red lines. Black lines on the dendrogram denote samples that are statistically different from one-another at the 5% significance level.

### *2.6.2 Notable taxa*

The potential for notable taxa, such as rare or protected species (Bratton, 1991; Sanderson, 1996; Betts, 2001; Chadd & Extence, 2004), non-native species (Eno et al., 1997; Reise et al., 1999; Goulletquer et al., 2002; Wolff, 2005; Gollasch & Nehring, 2006; Minchin, 2007; Minchin et al., 2013), or potentially un-described species was investigated, and the significance of these records is discussed below. Results were also reviewed for the presence of any Annex I habitats or Priority Marine Features.

# 3. Results

## 3.1 Health and Safety Incidence

There were no incidents, near misses or other health and safety issues to report under APEM's Health and Safety procedures.

## 3.2 General descriptions of areas

The three survey landfall zones were sandy beaches near Peterhead, northeast Scotland. Two of the beaches, Landfall D (Scotstown Beach) and Landfall E (Lunderton Beach) were located to the north of Peterhead, with Landfall D about 3 km north of Landfall E and 5 km north of Peterhead. The third landfall (Landfall F: Sandford Bay) was about 2 km south of Peterhead.

### *3.2.1 Landfall D (Scotstown Beach)*

Landfall D was an exposed sandy beach, extending about 4 km north to south between Rattray Head and a stony shoal near St Fergus, with the survey area about 2 km long, at the southern end, south of Annachie Burn and the St Fergus Gas Terminal.

**Figure 6. View facing NE towards St Fergus Gas Terminal from South of Landfall D near transect 4**

Annachie Burn itself was outside the survey area, but formed a small estuary with some standing water that may represent a reduced salinity habitat.

**Figure 7. View NW towards St Fergus Gas Terminal from Annachie Burn at North end of Landfall D**

The survey area was mainly a shallow sandy bay with smooth or rippled clean sand that gently sloped towards the shore. This area was approximately 300 m wide. On the upper shore, there was a clear distinction of drier sand that had a steeper slope and a weak strandline. Above the upper shore, there were sand dunes that spanned the entire survey area.

**Figure 8. View SE from D2L at Landfall D**

At the southern end of the beach and survey area, there was a low outcrop of bedrock and boulders colonised by algae, extending from the mid to lower shore. Sand and dunes extended behind the outcrop on the mid and upper shore. Algal zonation included an *Ulva* / *Porphyra* zone on the landward edge and other areas adjacent to the sand beach, with fucoid (*Fucus vesiculosus*, *F. serratus* and *Ascophyllum nodosum*) and barnacle zones in the centre and on the lower shore.

**Figure 9. Shoal at southern end of Landfall D, at transect 4**

### *3.2.2 Landfall E (Lunderton Beach)*

Landfall E was an exposed sandy beach, about 2 km long extending north to south between two ill-defined stony points. Most of the survey area comprised a shallow sandy bay with gently sloping smooth or rippled clean sand on the mid to lower shore, about 300 m wide. There was a clear demarcation of drier more steeply sloping sand on the upper shore with a weak strandline. There were sand dunes above the upper shore along the whole of the survey area.

**Figure 10. View N facing at Landfall E, from E4L**

The northern shoal was low and comprised medium boulders. It extended from the mid shore through fucoid zonation and barnacle biotopes, with *Ulva* and *Porphyra* adjacent to the sandy areas on either side and above (landward side).

**Figure 11. View facing N of shoal at the Northern end of Landfall E, from E1M**

The southernmost point, adjacent to Peterhead Golf Course, extended on to the upper shore almost to the dunes, with only a narrow strip of upper shore sand between the stones and dunes. It included some moderately high bedrock outcrops with *Verrucaria maura*, and extended down the shore through fucoid zonation and barnacle biotopes, with *Ulva* and *Porphyra* adjacent to the sandy areas to the North.

**Figure 12. Shoal at southern end of Landfall E, South of transect 4**

### *3.2.3 Landfall F (Sandford Bay)*

Landfall F was a moderately exposed sandy beach, about 1.16 km long extending north to south between the southern outskirts of Peterhead (Burnhaven) and the SSE Power Station. It was a horseshoe-shaped bay with hard substrata around most of its shoreline on the northern and southern sides and a shorter stretch of sand in the centre. There were industrial developments to the North (engineering works, sewage works) and South (Power Station), with outfall pipes on the southern shore.

**Figure 13. View facing S from car park off the shore of Landfall F: rocky shore, sandy beach and SSE power station**

Freshwater streams entered the bay on the northern side and a little to the south of the sandy area. They were too small to create significant areas of brackish water communities.

**Figure 14. Stream on northern end of shore of Landfall F**

**Figure 15. View facing W of stream at south end of sandy area of Landfall F**

The mid shore of the sandy area was gently sloping smooth sand on the mid to lower shore, about 100 m wide. The wet sand merged into drier sand on the upper shore with a strandline. There were sand dunes above the upper shore in the central, sandy, part of the bay.

**Figure 16. View facing S from F1U along sandy area of Landfall F**

The northern shore comprised bedrock outcrops and boulders, with grassy banks above the upper shore, sometimes with eroding low, sandy cliffs. The rocks showed fucoid zonation and barnacle-dominated biotopes. Several rockpools were noted.

**Figure 17. Intertidal rock biotopes and rockpool at northern end of Landfall F; sandy beach in distance**

The hard substrata on the southern shore included bedrock outcrops and boulders. There were grassy banks above the upper shore. Peterhead Power Station was immediately behind the shore over some of the area and many of the boulders below the power station appeared to have been placed as rock armour. The rocks showed fucoid zonation and barnacle-dominated biotopes. Several rockpools were noted.

**Figure 18. View facing NW across Landfall F from Seafood company and SSE power station; shore protection rock armour and outflow pipe at south end of Landfall F**

## 3.3 Intertidal sediments

### *3.3.1 Substratum characteristics with PSA*

All landfall zones included stretches of intertidal sand extending from dunes, through a dry upper shore zone, to mid and lower shore mobile sand. At Landfall D and Landfall E, this formed the majority of the area; at Landfall F, intertidal sand comprised a smaller proportion at the centre of the bay.

Photographs of each core sample are shown in Appendices 3, 4 and 5 (for Landfalls D, E and F, respectively). Raw PSA data are presented in Appendix 2 ; a summary is provided below in Table 3, Figure 19, Figure 20 and Figure 21. Almost all stations in all areas were classified as moderately well sorted 'Slightly Gravelly Sand', although D2U and E1U were classified as sand F1M as gravelly sand.

**Table 3. Summary of Particle Size Analysis data at each Landfall Zone**

| Station | Mean (µm) | Gravel (%) | Sand (%) | Mud (%) | Folk (1954) | Sorting |
|---|---|---|---|---|---|---|
| D1 Upper | 542.6 | 0.07 | 99.93 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| D1 Middle | 615.5 | 0.48 | 99.24 | 0.28 | Slightly Gravelly Sand | Moderately Well Sorted |
| D1 Lower | 573.2 | 0.07 | 99.63 | 0.30 | Slightly Gravelly Sand | Moderately Well Sorted |
| D2 Upper | 405.3 | 0.00 | 100.00 | 0.00 | Sand | Moderately Well Sorted |
| D2 Middle | 553.0 | 0.31 | 99.23 | 0.46 | Slightly Gravelly Sand | Moderately Well Sorted |
| D2 Lower | 482.5 | 0.34 | 99.18 | 0.49 | Slightly Gravelly Sand | Moderately Well Sorted |
| D3 Upper | 360.7 | 0.00 | 100.00 | 0.00 | Slightly Gravelly Sand | Well Sorted |
| D3 Middle | 526.9 | 0.45 | 99.42 | 0.13 | Slightly Gravelly Sand | Moderately Well Sorted |
| D3 Lower | 447.1 | 0.32 | 99.68 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| D4 Upper | 402.7 | 0.02 | 99.98 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| D4 Middle | 421.3 | 0.11 | 99.89 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| D4 Lower | 396.6 | 0.19 | 99.81 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E1 Upper | 389.5 | 0.00 | 100.00 | 0.00 | Sand | Moderately Well Sorted |
| E1 Middle | 390.1 | 0.02 | 99.98 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E1 Lower | 381.4 | 0.01 | 99.99 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E2 Upper | 462.8 | 0.02 | 99.98 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E2 Middle | 523.6 | 0.28 | 99.20 | 0.52 | Slightly Gravelly Sand | Moderately Well Sorted |
| E2 Lower | 532.4 | 0.17 | 99.34 | 0.49 | Slightly Gravelly Sand | Moderately Well Sorted |
| E3 Upper | 585.9 | 1.02 | 98.98 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E3 Middle | 571.3 | 0.09 | 99.74 | 0.17 | Slightly Gravelly Sand | Moderately Well Sorted |
| E3 Lower | 540.3 | 0.02 | 99.98 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E4 Upper | 483.6 | 0.00 | 100.00 | 0.00 | Slightly Gravelly Sand | Moderately Well Sorted |
| E4 Middle | 573.9 | 0.37 | 99.47 | 0.15 | Slightly Gravelly Sand | Moderately Well Sorted |
| E4 Lower | 455.4 | 0.05 | 99.39 | 0.56 | Slightly Gravelly Sand | Moderately Well Sorted |
| F1 Upper | 553.1 | 0.02 | 99.41 | 0.56 | Slightly Gravelly Sand | Moderately Well Sorted |
| F1 Middle | 501.3 | 6.90 | 92.47 | 0.62 | Gravelly Sand | Moderately Sorted |
| F1 Lower | 429.1 | 3.84 | 96.16 | 0.00 | Slightly Gravelly Sand | Moderately Sorted |

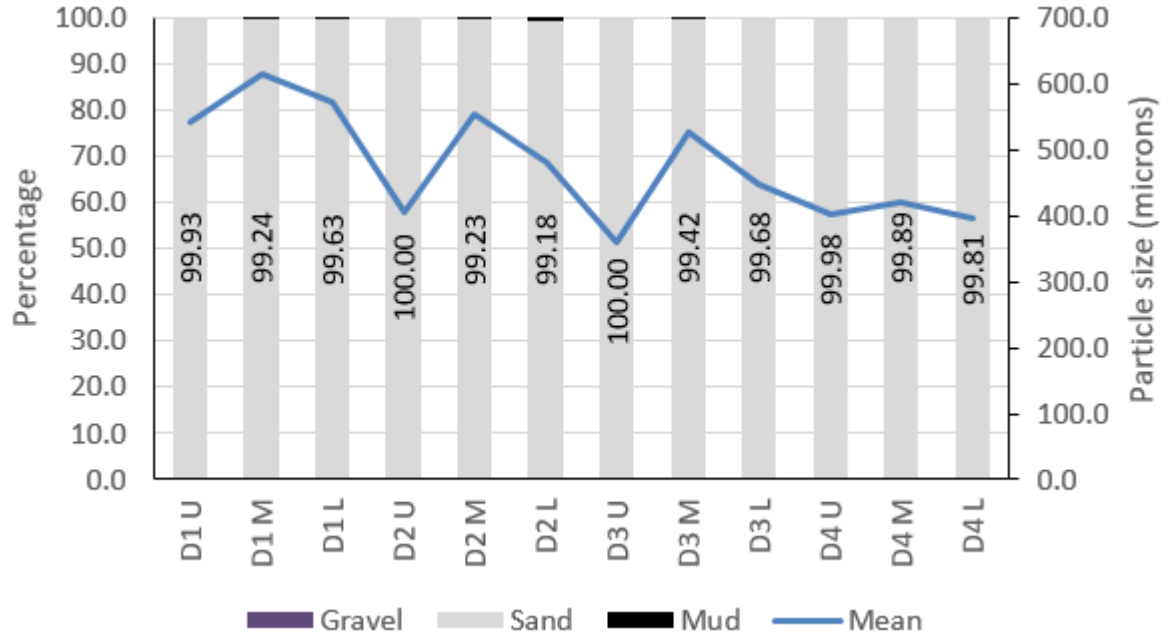


**Figure 19. Proportion of Gravel, Sand and Mud and mean particle size at each sampling station at Landfall D**

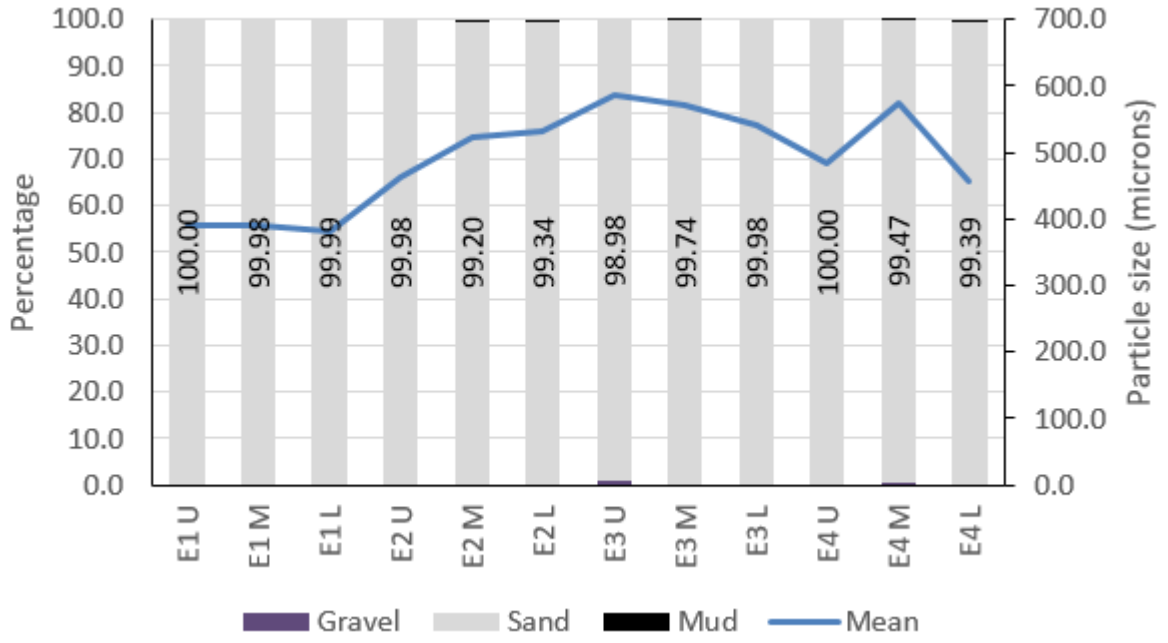


**Figure 20. Proportion of Gravel, Sand and Mud and mean particle size at each sampling station at Landfall E**

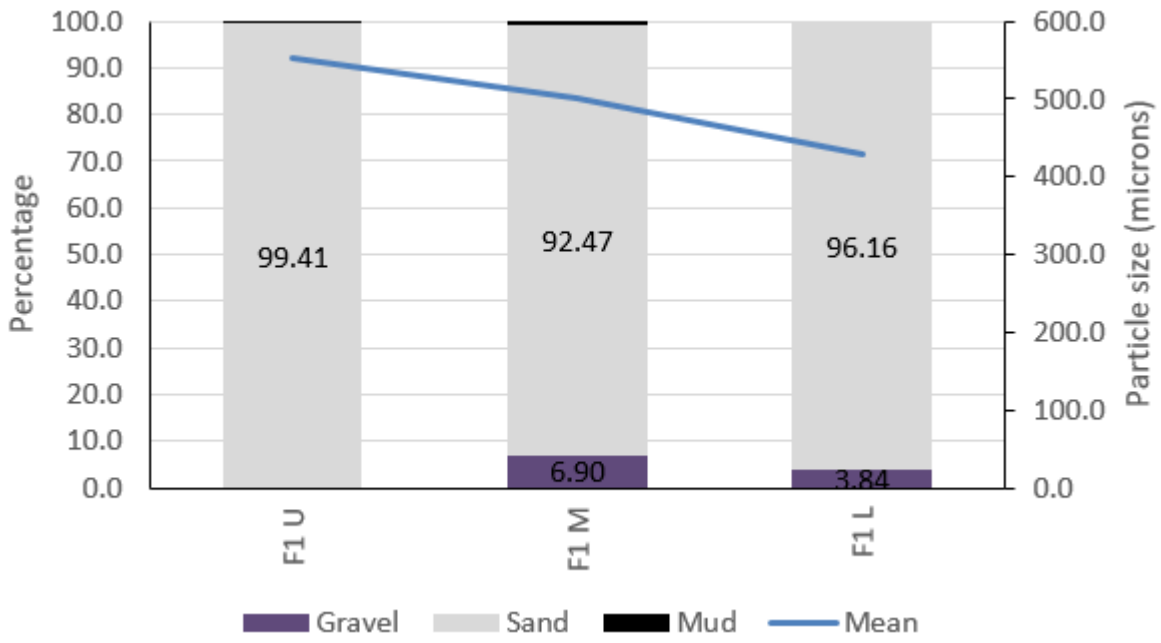


**Figure 21. Proportion of Gravel, Sand and Mud and mean particle size at each sampling station at Landfall F**

### *3.3.2 Macrobenthos (sediments)*

Raw biological data are presented in Appendix 2 for core samples and Appendix 6 for photographs of *in situ* quadrats. Mean abundance data for each sampling point, standardised to numbers per $m^2$, are presented for core samples in

Table 4, Table 5, and Table 6, below.

## Table 4. Abundance data per $m^2$ and univariate statistics for core samples from Landfall D

P = present, Frag. = Fragments

| Taxon Name | Qualifier | Station ID | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | D1U | D1M | D1L | D2U | D2M | D2L | D2U | D3M | D3L | D4U | D4M | D4L |
| Animalia | eggs | | | | | | | | | | | P | |
| Nemertea | | | | | | | 100 | | | 300 | | 100 | 1,900 |
| Nematoda | | | 100 | 300 | | 100 | 400 | | | | | | |
| *Paraonis fulgens* | | | | | | | | | | | | | 100 |
| *Malacoceros tetracerus* | | | | | | | | | | | | 100 | |
| *Scolelepis squamata* | | | 100 | | | 100 | | | 100 | | | 100 | 100 |
| *Tharyx killariensis* | | 100 | | | | | | | | | | | |
| *Protodriloides chaetifer* | | | | | | | | | | Frag. | | | |
| Enchytraeidae | | 1,200 | | Frag. | | | | 100 | | | | | |
| *Pontocrates arenarius* | | | 500 | 700 | | | 1,200 | | 100 | 2,400 | | 400 | 300 |
| Talitridae | juvenile | | | | | | | 800 | | | 100 | | |
| *Talitrus saltator* | | | | | | | | 100 | | | 400 | | |
| *Bathyporeia pelagica* | | | | | | | | | | | | 200 | 100 |
| *Bathyporeia sarsi* | | | | | | | | | | | | | 300 |
| *Haustorius arenarius* | | | | 100 | | | 800 | | | | | 100 | |
| *Eurydice affinis* | | | | | | | | | 100 | 100 | | 500 | 300 |
| *Eurydice pulchra* | | | 300 | | | 300 | | | | | | | |
| Diptera | larva | Frag. | | | | | | | | | | | |
| Limoniidae | larva | 100 | | | 100 | | | | | | | | |
| Penetrantiidae | | P | | | P | | P | | | | | | |
| Total No. Taxa | | 4 | 4 | 3 | 2 | 3 | 5 | 2 | 3 | 3 | 1 | 8 | 7 |
| Total No. Individuals | | 14 | 10 | 11 | 1 | 5 | 25 | 10 | 3 | 28 | 5 | 15 | 31 |
| Margalef's Species Richness (D) | | 0.76 | 1.30 | 0.83 | - | 1.24 | 0.93 | 0.43 | 1.82 | 0.60 | - | 2.22 | 1.75 |
| Pielou's Evenness (J') | | 0.46 | 0.84 | 0.78 | - | 0.86 | 0.82 | 0.47 | 1.00 | 0.45 | - | 0.88 | 0.67 |
| Shannon Wiener Diversity (H') $\log_e$ | | 0.51 | 1.17 | 0.86 | - | 0.95 | 1.14 | 0.33 | 1.10 | 0.49 | - | 1.71 | 1.31 |
| Simpson Diversity (1-λ') | | 0.27 | 0.71 | 0.56 | - | 0.70 | 0.67 | 0.20 | 1.00 | 0.26 | - | 0.84 | 0.61 |

## Table 5. Abundance data per $m^2$ and univariate statistics for core samples from Landfall E

P = present, N = No Biota, Frag. = Fragments

| Taxon Name | Qualifier | Station ID | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | E1U | E1M | E1L | E2U | E2M | E2L | E3U | E3M | E3L | E4U | E4M | E4L | WP91 | WP121 |
| No Biota | | | | | | | | | | | | | | N | |
| Animalia | eggs | | | | | | P | | | | | | | | P |
| *Lovenella clausa* | | | | | | | | | | | | P | | | |
| Nemertea | | | 800 | | | | | | | 300 | | | | | |
| Nematoda | | | | | | | 200 | | | 200 | | 1,500 | 300 | | |
| Sagittidae | | | | | | | | Frag. | | | 100 | | | | |
| *Pisione remota* | | | | | | | | | | 100 | | | | | |
| *Scolelepis squamata* | | | 100 | 100 | | 100 | | | | 100 | | Frag. | 200 | | |
| *Capitella* | | | 100 | | | | | | | | | | | | |
| *Arenicola marina* | | 100 | | | | | | | | | | | | | |
| *Protodriloides chaetifer* | | | | | | | 400 | | | 500 | | | 100 | | |
| *Baltidrilus costatus* | | | Frag. | | | | | | | | | | | | |
| Enchytraeidae | | | | | | | | | | | 800 | | | | |
| Copepoda | | | | | | | | | | 100 | | | | | |
| *Pontocrates arenarius* | | | | 400 | | | 300 | | 100 | 200 | | | 200 | | |
| Talitridae | juvenile | | | | 100 | | | | | | 1,400 | | | | |
| *Talitrus saltator* | | 400 | | | | | | 300 | | | 100 | | | | |
| *Bathyporeia pelagica* | | | 300 | 1,200 | | | | | | | | | | | |
| *Bathyporeia sarsi* | | | 1,400 | | | | | | | | | | | | |
| *Haustorius arenarius* | | | 300 | 300 | | 400 | | | | 100 | | | 100 | | |
| *Eurydice pulchra* | | | 100 | | | | | | | 100 | | | 100 | | |
| Coleoptera | larva | | | | | | | | | | 100 | | | | |
| Limoniidae | larva | | | | | | | | | | 100 | | | | |
| *Mya truncata* | juvenile | | | | | | | | | 100 | | | | | |
| Total No. Taxa | | 2 | 7 | 4 | 1 | 2 | 4 | 1 | 1 | 10 | 5 | 2 | 6 | 0 | 1 |
| Total No. Individuals | | 5 | 31 | 20 | 1 | 5 | 9 | 3 | 1 | 18 | 26 | 15 | 10 | 0 | 0 |
| Margalef's Species Richness (D) | | 0.62 | 1.75 | 1 | - | 0.62 | 0.91 | 0 | - | 3.11 | 1.23 | - | 2.2 | | |
| Pielou's Evenness (J') | | 0.72 | 0.77 | 0.77 | - | 0.72 | 0.97 | - | - | 0.91 | 0.66 | - | 1 | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Shannon Wiener Diversity (H') $\log_e$ | 0.5 | 1.49 | 1.06 | - | 0.5 | 1.06 | - | - | 2.11 | 1.06 | - | 1.7 | | |
| Simpson Diversity (1-λ') | 0.4 | 0.73 | 0.61 | - | 0.4 | 0.72 | - | - | 0.9 | 0.59 | - | 0.9 | | |

**Table 6. Abundance data per $m^2$ and univariate statistics for core samples from Landfall F**

P = present, Frag. = Fragments

| Taxon Name | Qualifier | Station ID | | |
|---|---|---|---|---|
| | | F1U | F1M | F1L |
| Animalia | eggs | P | P | |
| Nemertea | | | 100 | 2,000 |
| Nematoda | | | | 100 |
| *Microphthalmus* | | | | 200 |
| *Malacoceros* | juvenile | | | 200 |
| *Malacoceros tetracerus* | | | | 400 |
| *Scolelepis squamata* | | | 100 | 300 |
| *Capitella* | | | | 300 |
| *Arenicola marina* | | | | 100 |
| Enchytraeidae | | 600 | 100 | |
| *Pontocrates arenarius* | | | 200 | |
| Talitridae | juvenile | 1,300 | | |
| *Talitrus saltator* | | 200 | | |
| *Bathyporeia pelagica* | | | | 300 |
| *Bathyporeia sarsi* | | | | 100 |
| *Haustorius arenarius* | | | 100 | 900 |
| *Cumopsis goodsir* | | | | 400 |
| *Alcyonidium diaphanum* | | | | P |
| Total No. Taxa | | 3 | 6 | 12 |
| Total No. Individuals | | 21 | 6 | 53 |
| Margalef's Species Richness (D) | | 0.33 | 2.23 | 2.52 |
| Pielou's Evenness (J') | | 0.86 | 0.97 | 0.81 |
| Shannon Wiener Diversity (H') $\log_e$ | | 0.60 | 1.56 | 1.95 |
| Simpson Diversity (1-λ') | | 0.43 | 0.93 | 0.81 |

Thirty-three taxa were recorded from the sediment core samples across the three landfall zones. These included eggs, fragments, some unattached sessile taxa (*Alcyonidium diaphanum*) and others (*Tharyx killariensis*) that may have been washed up from the subtidal, and some that represented juveniles of species identifiable only as adults (e.g. *Malacoceros*, Talitridae). Twenty-three taxa were recorded, after rationalisation. In upper shore samples, the most widespread taxa were enchytraeid oligochaete worms, fly larvae (Limoniidae) and sandhoppers (Talitridae, *Talitrus saltator*). In the mid and lower shore samples, there were nemertean and nematode worms, the polychaete worms *Scolelepis squamata*, *Protodriloides chaetifer* and *Arenicola marina* (lugworm), the amphipod Crustacea *Pontocrates arenarius*, *Bathyporeia pelagica*, *B. sarsi* and *Haustorius arenarius*, together with smaller numbers of isopod and cumacean Crustacea. One core sample (at WP 91) contained no biota. None of the animals were found in high numbers; the highest count in a single sample was for *Pontocrates arenarius* (24 in D3L: 2,400 per $m^2$).

## 3.4 Hard substrata

### *3.4.1 Substratum characteristics*

Hard substrata were present in all three landfall zones. At the southern end of Landfall D, there was an indistinct headland with bedrock (Peterhead granite) outcropping on the mid shore. Boulders and cobbles of a range of sizes surrounded the rock on all sides. Similar promontories were present at the northern and southern limits of Landfall E, though the northern boulder patch lacked noticeable bedrock. At Landfall F, there were extensive bedrock outcrops along the northern and southern shores, both with a wide range of boulder and cobble sizes within and surrounding the rock. Some of the upper shore boulders had been placed as rock armour and it was sometimes difficult to distinguish between naturally distributed and artificially placed or collapsed boulder piles at Landfall F. In all areas of natural rock, there were clefts, gullies and rockpools, especially on either side of Landfall F.

### *3.4.2 Macrobenthos (quadrat data)*

Raw data for macrobiota from the quadrats are presented in Table 7 and photographs of quadrats are shown in Appendix 7 .

**Table 7. Abundance data per $m^2$ in Quadrat samples**

| Taxon name | Landfall F | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | F2U | F2M | F2L | F3U | F3M | | F3L | |
| | % | % | % | % | % | count | % | count |
| Bare Rock | 100 | | | 100 | | | | |
| Dead seaweed | | | | | | | 100 | |
| Dead *Fucus vesiculosus* stipes | | | | | | | 20 | |
| *Fucus vesiculosus* | | 2 | | | | | | |
| *Fucus serrratus* | | | 12 | | | | | |
| *Ulva* | | 16 | 16 | | | | 1 | |
| *Chondrus* | | 8 | | | | | | |
| *Ceramium* | | 4 | 2 | | | | | |
| *Rhodothamniella* | | 70 | 44 | | | | | |
| *Mastocarpus* | | | 24 | | | | | |
| *Osmundea pinnatifida* | | | 2 | | 4 | | 4 | |
| *Aglaothamniom* | | | <1 | | | | | |
| *Patella vulgata* | | | | | | 52 | | 55 |
| Rock and *Chthamalus* | | | | | 96 | | 75 | |
| *Dumontia* | | | | | | | <1 | |
| *Littorina saxatilis* | | | | | | 3 | | |
| Total | 100 | 100 | 100 | 100 | 100 | - | 200 | - |

There were no biota recorded (bare rock) where the upper shore (supralittoral) quadrats were placed. At F2, mid shore quadrats were dominated by fine red algae (*Rhodothamniella*), while the lower shore included a wider range of fucoid and red algae. At F3 both mid and lower shore quadrats were dominated by barnacles (*Chthamalus*) and limpets (*Patella vulgata*). At F3L percentage cover was greater than 100% since dead seaweed overlayed other biota.

Other species were noted for the wider area (see Appendix 7 ).

## 3.5 Calculated indices

The core samples collected from three different landfall zones showed low numbers of individuals and taxa. Some values were unattainable for diversity indices tests due to the absence or scarcity of biota. The Shannon Wiener diversity ((H') $\log_e$) values ranged from 0.33 in an upper shore (D3U) sample to the highest value of 2.11 at a lower shore (E3L) station across all three landfall zones.

For the cores collected at Landfall D, the Shannon Wiener diversity ((H') $\log_e$) values varied between 0.33 at D3U to 1.71 at D4M. In contrast, the Simpson diversity measure ranged from 0.20 at D3U to 1.00 at D3M. The Margalef's species richness (D) had higher values towards the SE end of the shore at F4 and ranged from 0.43 at D3U to 2.22 at D4M. The Pielou's Evenness (J') values for the core samples at Landfall D ranged from 0.45 at D3L to 1.00 at D3M. An average from each set of upper, middle, and lower core samples indicated that the highest diversity was in the middle level of the beach, and the lowest value was in the upper shore.

At Landfall E, the cores showed the lowest and highest diversity values at the same positions on the shore. The highest numbers of taxa and individuals were found in the upper and middle shore. The Shannon Wiener diversity ((H') $\log_e$) values ranged from 0.50 at E1U and E2M to 2.11 at E3L. The Simpson diversity measure ranged from 0.40 at E1U and E2M to 0.90 at E3L, which were also the highest and lowest stations for Shannon Wiener diversity. The Margalef's species richness (D) had a wide range from 0.00 at E3U to 3.11 at E3L, and the Pielou's Evenness (J') values at Landfall E ranged from 0.66 at E4U to 0.97 at E2L. An average from each set of upper, middle, and lower core samples at Landfall E indicated that the highest diversity was in the upper level of the beach, and the lowest was split between the upper and lower parts of the shore.

Cores were only collected at Transect 1 (F1) at Landfall F due to the rocky structure of the bay around transects 2 and 3. The Shannon Wiener diversity ((H') $\log_e$) values were lowest at F1U with 0.60, medium at F1M with 1.56, and highest at F1L with 1.95. The Simpson diversity values were lowest at F1U with 0.43, medium at F1L with 0.81, and highest at F1M with 0.93. The Margalef's species richness (D) ranged from 0.33 at F1U to 2.52 at F1L, and

the Pielou's Evenness (J') values ranged from 0.81 at F1L to 0.97 at F1M. The highest values were from the lower and mid shore, with the lowest values at upper shore stations; the numbers of individuals and taxa were highest on the lower shore.

## 3.6 Cluster Analysis

The results of SIMPROF cluster analysis on the macrobenthic data for each station are presented in Figure 22. Black lines denote significant structure within the group to that point and red lines connect samples that cannot be significantly differentiated at the 95% confidence interval. The SIMPROF test identified three groups (Group a-c) that can be considered statistically distinct from one-another at the 95% confidence level, one of which comprised a single sample.

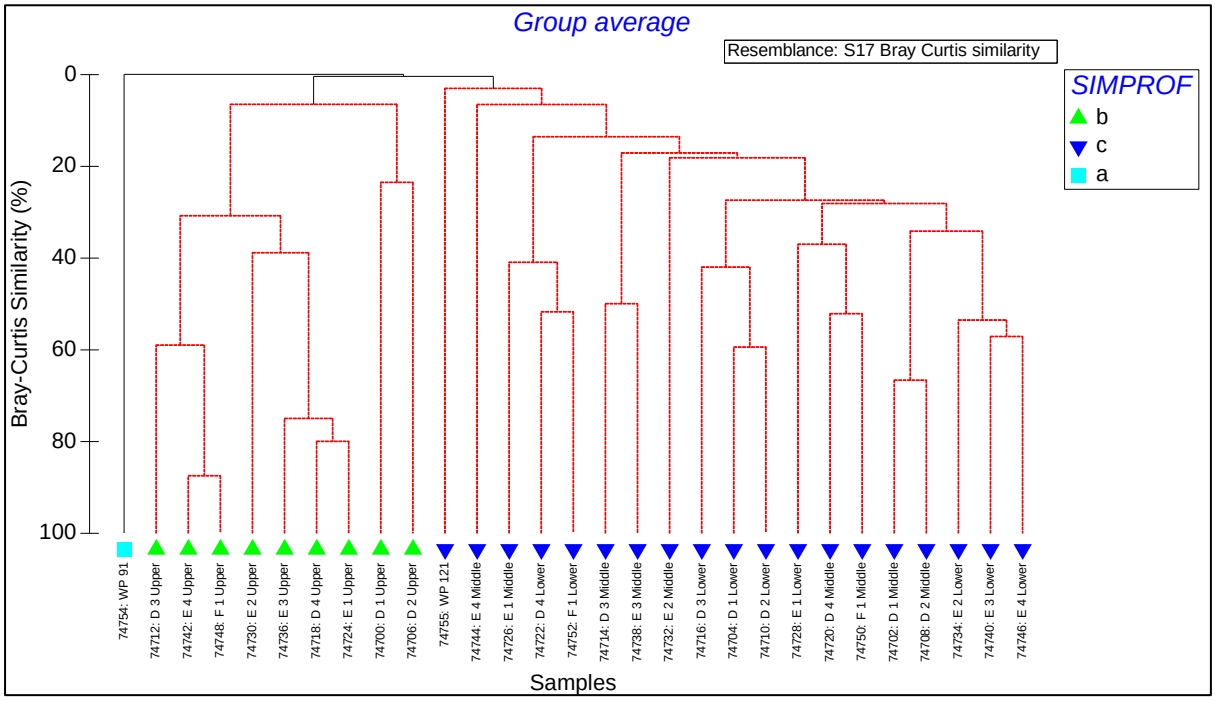


**Figure 22. SIMPROF Cluster dendrogram of Bray-Curtis similarity between samples. Different colours and symbols denote SIMPROF Groups.**

Group A comprised the single sample collected from the anoxic sand at WP91 at Landfall E. This sample contained no fauna and separated from groups B and C at a similarity of 2.67%. Groups B and C separated from one-another at 2.82% similarity. Group B included the 9 upper shore samples from all three landfall locations and was characterised by the sandhopper *Talitrus saltator*, which was the only taxon recorded in most of the upper shore samples. Group C included 19 samples collected from the middle and lower shore along with the additional sample collected at WP121 at Landfall E. There were no clear patterns of inter-site variability, with samples from each landfall mixed together across the dendrogram

and the main intra-site variability was shore zonation, with upper shore samples from all landfalls clearly separated from the middle and lower shore samples.

## 3.7 Notable taxa

No non-native species (NNS) were recorded from the core samples. No British Red Data Book (Bratton, 1991) or protected species (Betts, 2001) were recorded.

The polychaete *Capitella* sp. was recorded in two samples from these surveys with 1 individual in sample E1M and three individuals at F1L. These worms can be representative of organic enrichment when found in high numbers, but the low numbers in these surveys would not indicate any enrichment at these stations and the Total Organic Carbon data for corresponding samples (reported in APEM, 2023) does not indicate elevated levels, although it should be noted that, since contaminant samples were only obtained at the mid-shore stations, the data for F1 are not directly applicable.

## 3.8 Biotope assignments

Hard substratum biotopes mapped in the field are included in

Table **8** below, together with those assigned to core samples. Biotopes are mapped for each of the three zones in Figures 22 to 24, below.

**Table 8. Biotope description and codes for each landfall zone**

| JNCC Code | Description | EUNIS Code (2022) | EUNIS code (2012) | Landfall | | |
|---|---|---|---|---|---|---|
| | | | | D | E | F |
| LR.FLR.Lic.YG | Yellow and grey lichens on supralittoral rock | MA121 | B3.111 | | | ✓ |
| LR.FLR.Lic.Ver | *Verrucaria maura* on littoral fringe rock | MA1213 | B3.113 | | | ✓ |
| LR.HLR.MusB.Sem | *Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock | MA1223 | A1.113 | ✓ | ✓ | ✓ |
| LR.LLR.F.Fspi | *Fucus spiralis* on moderately exposed to very sheltered upper eulittoral rock | MA123C | A1.312 | | | ✓ |
| LR.LLR.F.Fves | *Fucus vesiculosus* on moderately exposed to sheltered mid eulittoral rock | MA123D | A1.313 | ✓ | ✓ | ✓ |
| LR.LLR.F.Asc | *Ascophyllum nodosum* on very sheltered mid eulittoral rock | MA123E | A1.314 | ✓ | | ✓ |
| LR.FLR.Eph.UlvPor | *Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock | MA123H | A1.452 | ✓ | ✓ | ✓ |
| LR.MLR.BF.PelB | *Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock | MA1241 | A1.211 | | | ✓ |
| LR.MLR.BF.Fser | Fucus serratus on moderately exposed lower eulittoral rock | MA1244 | A1.214 | ✓ | ✓ | ✓ |
| LS.LSa.St.Tal | Talitrids on the upper shore and strandline | MA5211 | A2.211 | ✓ | ✓ | ✓ |
| LS.LSa.MoSa.BarSa | Barren Atlantic littoral coarse sand | MA5231 | A2.221 | ✓ | ✓ | |
| LS.LSa.MoSa.Ol.FS | Oligochaetes in full salinity Atlantic littoral mobile sand | MA52321 | A2.2221 | ✓ | | |
| LS.LSa.MoSa.AmSco | Amphipods and *Scolelepis* spp. in littoral medium-fine sand | MA5233 | A2.223 | ✓ | ✓ | ✓ |
| LS.LSa.MuSa.MacAre | Polychaete/bivalve-dominated Atlantic littoral muddy sand | MA525 | A2.24 | | | ✓ |
| IR.MIR.KR.Ldig | *Laminaria digitata* on moderately exposed Atlantic sublittoral fringe rock | MB1217 | A3.211 | | | ✓ |

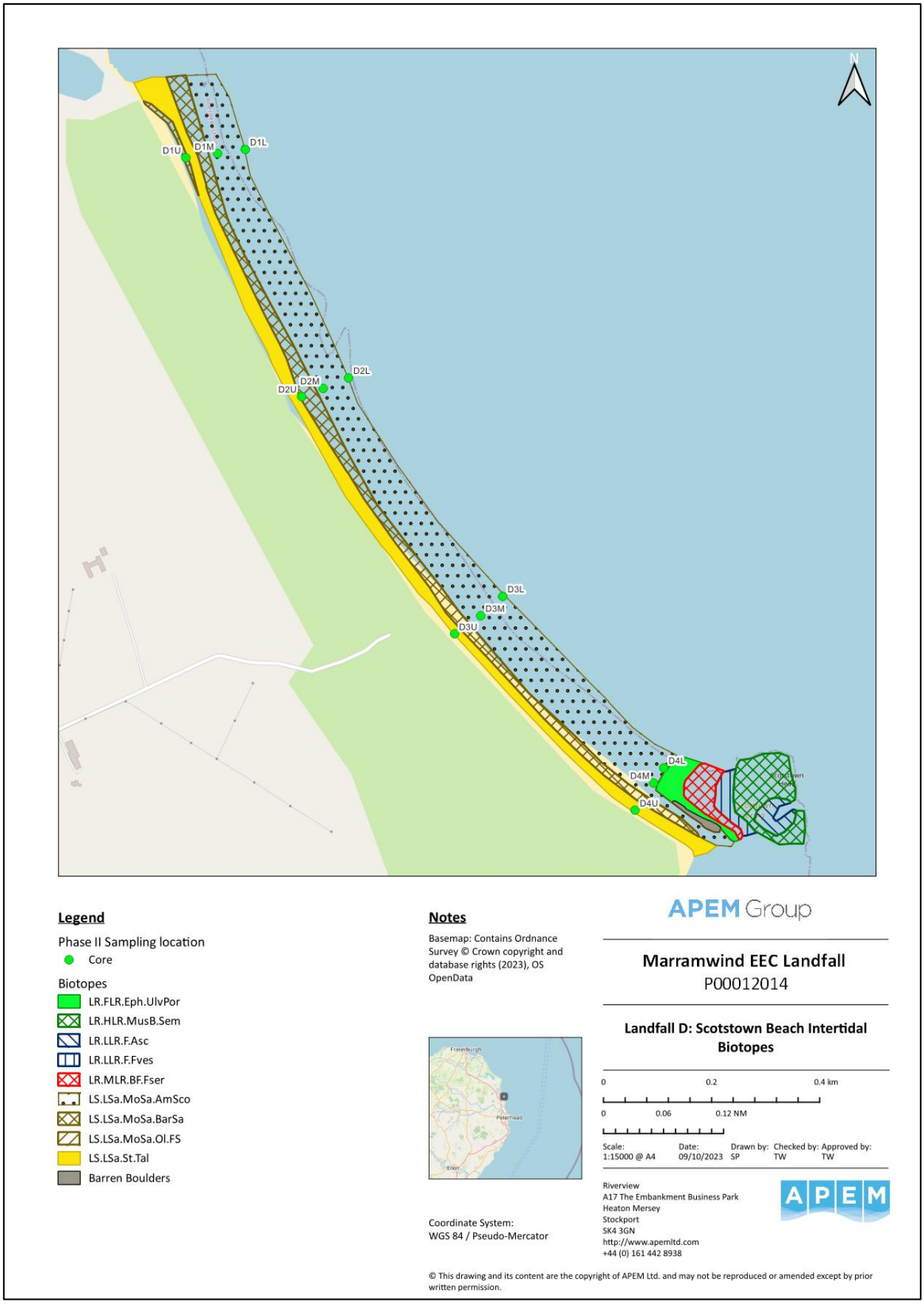


**Figure 23. Biotope map for Landfall D**

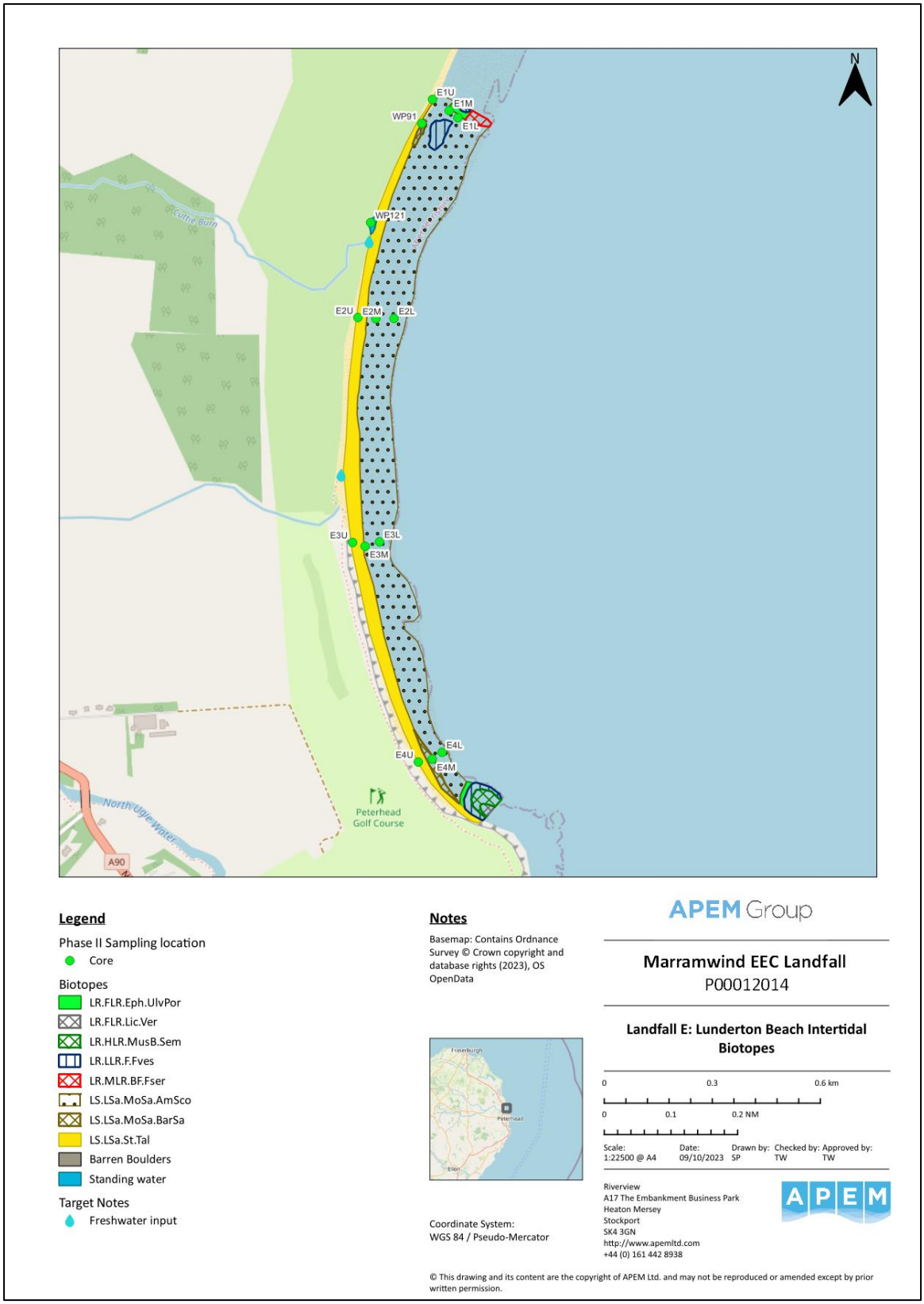


**Figure 24. Biotope map for Landfall E**

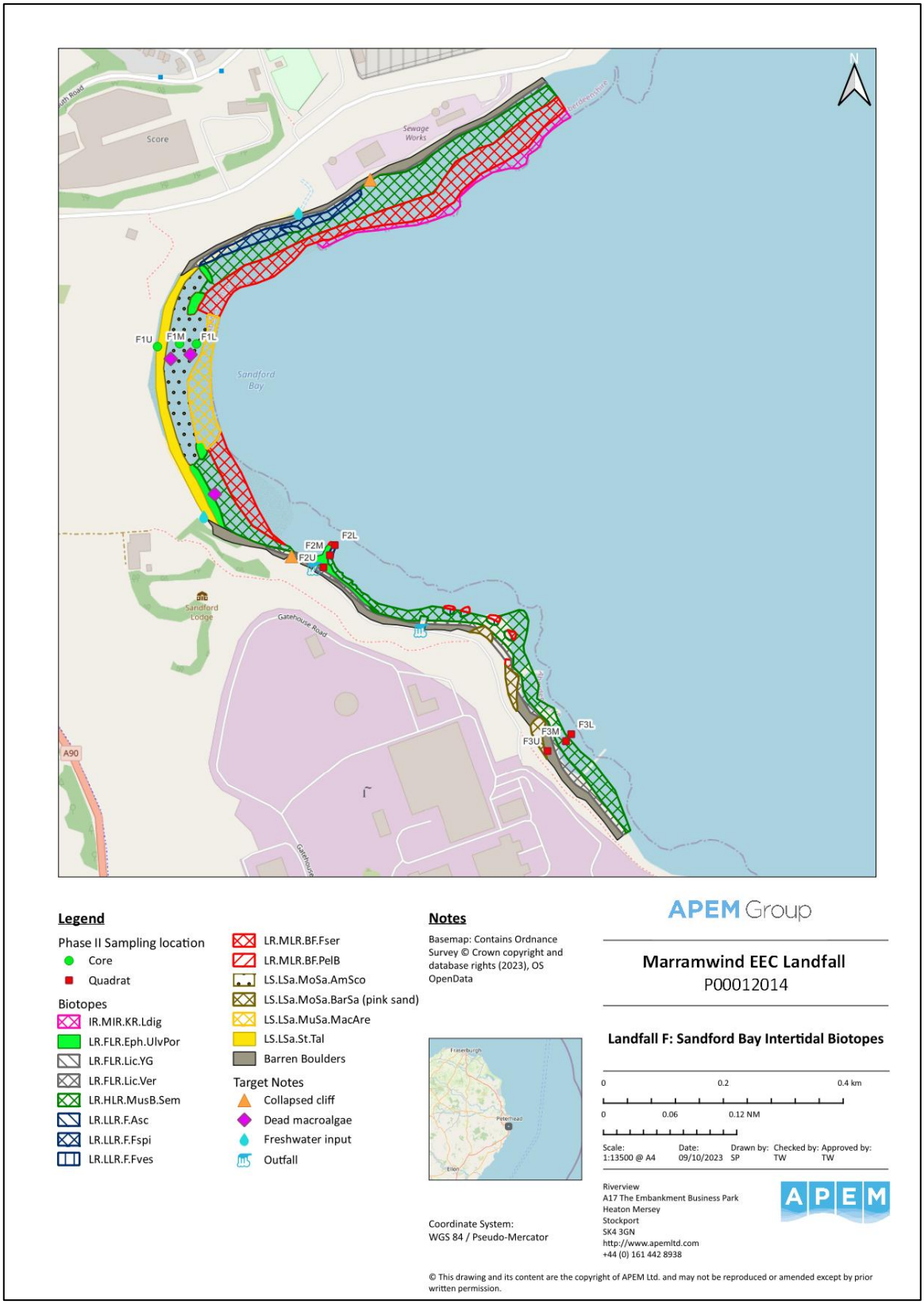


**Figure 25. Biotope map for Landfall F**

### *3.8.1 Littoral rock (LR; MA1) biotopes*

Some of the upper shore boulders, particularly at Landfall F, were without obvious biota and are described on the maps as 'barren boulders', without a biotope designation. There were also areas of rock armour and collapsed cliffs (mainly above high water level) at Landfall F.

e 

**Figure 26. Barren boulders at northern end of Landfall F near to northern stream**

Upper shore rocks on the northern and southern edges of Landfall F fitted LR.FLR.Lic.YG (Yellow and grey lichens on supralittoral rock; MA1211; B3.111). Most were dominated by *Ramalina* sp.

**Figure 27. LR.FLR.Lic.YG, Landfall F between transect F2 and F3**

There were also areas of LR.FLR.Lic.Ver (*Verrucaria maura* on littoral fringe rock; MA1213; B3.113) on upper shore rocks on the northern and southern edges of Landfall F.

**Figure 28. LR.FLR.Lic.Ver, View facing SE on Landfall F between transect F2 and F3**

Rocks and boulders on the mid shore fitted LR.HLR.MusB.Sem (*Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock). There were relatively large areas around Landfall F, with additional patches at the southern ends of the two other beaches. The biotope could be considered divided between LR.HLR.MusB.Sem.Sem (*Semibalanus balanoides*, *Patella vulgata* and *Littorina* spp. on exposed to moderately exposed or vertical sheltered eulittoral rock) on bedrock and larger boulders, with LR.HLR.MusB.Sem.LitX (*Semibalanus balanoides* and *Littorina* spp. on exposed to moderately exposed eulittoral boulders and cobbles, MA12233, A1.1133) on smaller boulders and cobbles.

**Figure 29. LR.HLR.MusB.Sem, Landfall F**

There were upper shore boulders and cobbles dominated by *Fucus spiralis*, LR.LLR.F.Fspi (*Fucus spiralis* on moderately exposed to very sheltered upper eulittoral rock; MA123C; A1.312) at the northern edge of Sandford Bay. Patches on smaller boulders and cobbles could represent the sub-biotope LR.LLR.F.Fspi.X (*Fucus spiralis* on full salinity upper eulittoral mixed substrata; MA123C2; A1.3122).

**Figure 30. LR.LLR.F.Fspi, Landfall F**

Small areas of southern Landfall F and parts of the boulder headlands at the southern ends of both Landfall D and Landfall E were dominated by *Fucus vesiculosus*, LR.LLR.F.Fves (*Fucus vesiculosus* on moderately exposed to sheltered mid eulittoral rock; MA123D; A1.313). They fitted the sub-biotope LR.LLR.F.Fves.FS (*Fucus vesiculosus* on full salinity moderately exposed to sheltered mid eulittoral rock; MA123D1; A1.3131).

**Figure 31. LR.LLR.F.Fves on northern shore of Landfall F**

A small area of northern Landfall F and parts of the boulder headland at the southern end of Landfall D were dominated by *Ascophyllum nodosum*, LR.LLR.F.Asc (*Ascophyllum nodosum* on very sheltered mid eulittoral rock, MA123E; A1.314).

**Figure 32. LR.LLR.F.Asc on northern shore of Landfall F**

LR.FLR.Eph.UlvPor (*Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock; MA123H; A1.452) was found on boulders near sand at all landfall zones. There were scattered patches all around Landfall F, a zone across the edge of the boulder patch to the South of Landfall D and patches at both ends of Landfall E.

**Figure 33. LR.FLR.Eph.UlvPor, Landfall F**

A small upper shore zone of *Pelvetia canaliculata*, LR.MLR.BF.PelB (*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock, MA1241, A1.211), was noted on southern Landfall F.

**Figure 34. LR.MLR.BF.PelB, Landfall F**

There were small patches of boulders on the lower shore that fitted LR.MLR.BF.Fser (*Fucus serratus* on moderately exposed lower eulittoral rock, MA1244, A1.214). They were distributed across southern Landfall F and within the boulder patches to the South of Landfall D and northern Landfall E. In some areas, under-boulder fauna were noted, LR.MLR.BF.Fser.Bo (*Fucus serratus* and under-boulder fauna on exposed to moderately exposed lower eulittoral boulders, MA12442, A1.2142).

**Figure 35. LR.MLR.BF.Fser, Landfall F**

### *3.8.2 Littoral sand (LS; MA5) biotopes*

The dominant upper shore biotope in all landfall zones was LS.LSa.St.Tal (Talitrids on the upper shore and strandline; MA5211; A2.211). Strandlines were observed on each beach and talitrid amphipods (all adults were *Talitrus saltator*) were found in the core samples.

**Figure 36. LS.LSa.St.Tal, Landfall D**

LS.LSa.MoSa.BarSa (Barren Atlantic littoral coarse sand; MA5231; A2.221) was recorded from core data at D2U (Landfall D), as well as at E4M and the two additional samples at Landfall E. Areas of anoxic sand were noted on the upper shore at Landfall E (WP91), without biota, but the sand may not have been mobile. Areas of 'pink sand' at Landfall F also fitted this biotope.

Another low abundance biotope, LS.LSa.MoSa.Ol.FS (Oligochaetes in full salinity Atlantic littoral mobile sand; MA52321; A2.2221) was extrapolated from sample data for D1U (Landfall D). We have used this assignment for a strandline community dominated by enchytraeid oligochaetes.

The lower and mid shore sediments were mostly assigned to LS.LSa.MoSa.AmSco (Amphipods and *Scolelepis* spp. in littoral medium-fine sand: MA5233: A2.223LS) for most of the area of all landfall zones. Most samples were assigned to the sub-biotope LSa.MoSa.AmSco.Pon (*Pontocrates arenarius* in Atlantic littoral mobile sand; MA52333), with some belonging to LS.LSa.MoSa.AmSco (Amphipods and *Scolelepis* spp. in Atlantic littoral medium-fine sand; MA5233).

**Figure 37. LS.LSa.MoSa.AmSco, Landfall E**

Parts of the mid to lower shore at Landfall F were assigned in the field to LS.LSa.MuSa.MacAre (*Macoma balthica* and *Arenicola marina* in littoral muddy sand; MA5251; A2.241). It was defined by lugworm (*Arenicola marina*) casts noted in the field.

### *3.8.3 Infralittoral rock (IR; MB1) biotope*

Where the sublittoral fringe was exposed on the lower shore, areas of IR.MIR.KR.Ldig (*Laminaria digitata* on moderately exposed Atlantic sublittoral fringe rock; MB1217; A3.211) could be seen. This was only observed on the northern edge of Landfall F but may have been present elsewhere and unseen due to tidal states.

**Figure 38. IR.MIR.KR.Ldig on northern shore of Landfall F**

### *3.8.4 Areas of freshwater influence*

Small streams were noted at Landfall F, one at the most northern end (Figure 14) and a smaller one at the southern side of the sandy area of the bay (Figure 15) but none large enough to represent an estuarine biotope. Two of the streams developed small areas of standing water where they met the shore. A sample from one (WP121), had limited biota and no lagoonal biotopes were recorded.

**Figure 39. Stream on North side of Landfall E**

## 4. Discussion

Each of the three landfall zone options was within a bay divided between two major habitat types: intertidal sediment and intertidal hard substrata. The two sites to the North of Peterhead (Landfall D and Landfall E) were long, shallow bays extending over 1 km north to south, with wide (over 100 m) sandy beaches, with sand dunes above the high tide level. There were rocky areas at the northern and southern extremities of each of these beaches (at Landfall D, the northern promontory, Rattray Head, was outside the survey area). The landfall zone to the south of Peterhead (Landfall F) was a deeper, horseshoe-shaped bay, with a narrower, less extensive area of intertidal sand and longer stretches of hard substrata on its northern and southern shores. All areas had freshwater input from small streams at one or more points within or near the survey area.

Only the southern portion of Landfall D, south of the St Fergus Gas Terminal and Annachie Burn, was included within the survey area. Excluding the gas terminal, the only obvious anthropogenic influences were light litter and occasional pill boxes. Anthropogenic influences were also limited at Landfall E. Landfall F was more heavily influenced. It bordered the urbanized area of Peterhead on its northern shore, including a sewage works and industrial plant, with associated discharges and foreshore modification (rock armour on the upper shore). Similarly, the southern shore bordered the Peterhead Power Station, also with rock armour and discharges.

All three landfall zones included similar intertidal sand habitats in their central areas. At Landfall D and Landfall E, most of the area was mid shore, moderately well-sorted, slightly gravelly sand, with amphipod and polychaete communities fitting the biotope LS.LSa.MoSa.AmSco (Amphipods and *Scolelepis* spp. in littoral medium-fine sand: MA5233: A2.223LS) and its sub-biotopes, with an upper shore strandline of LS.LSa.St.Tal (Talitrids on the upper shore and strandline; MA5211; A2.211) and smaller areas of reduced diversity sandy areas. At Landfall F, similar biotopes were present in the central area, with some areas of more stable sand on the lower shore with more lugworm (*Arenicola marina*).

Hard substrata were present at the northern and southern extremities of each zone. At Landfall D, the northern promontory (Rattray Head) was outside the designated survey area but, to the south, a low headland extended to bedrock outcrops and boulders on the mid to lower shore (sand on the upper shore throughout). The rocks included scoured areas near the sand, fitting LR.FLR.Eph.UlvPor (*Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock; MA123H; A1.452), with fucoid zonation further in to the outcrop: LR.LLR.F.Fves (*Fucus vesiculosus* on moderately exposed to sheltered mid eulittoral rock; MA123D; A1.313), LR.LLR.F.Asc (*Ascophyllum nodosum* on very sheltered mid eulittoral rock, MA123E; A1.314) and LR.MLR.BF.Fser (*Fucus serratus* on moderately exposed lower eulittoral rock, MA1244, A1.214). The more exposed areas were colonised by barnacle and limpet communities: LR.HLR.MusB.Sem (*Semibalanus balanoides* on exposed to moderately exposed or vertical sheltered eulittoral rock). Similar patterns were recorded at either end of Landfall E, but no bedrock was seen at the northern boulder patch and, at the southern outcrop, the highest rocks were lichen-covered: LR.FLR.Lic.Ver (*Verrucaria maura* on littoral fringe rock; MA1213; B3.113). There were some rockpools at each of the stony areas, best developed where bedrock outcropped at the southern end of each of the long beaches. Hard substrata were more extensive at Landfall F, where there was a more complete zonation on both northern and southern shores, with additional lichen and fucoid biotopes, together with kelp on the lower shore on the north shore: IR.MIR.KR.Ldig (*Laminaria digitata* on moderately exposed Atlantic sublittoral fringe rock; MB1217; A3.211), though this may have been missed due to the tidal state in the other zones. Rockpools were more common and better developed on both shores of Landfall F than in the other landfall zones.

None of the species recorded were non-native or considered to be of conservation importance. The species of the mobile sand habitats comprising most of the proposed cable corridor landfall areas have opportunistic life history strategies, with short lifespans, rapid maturation and extended reproductive periods and can withstand sediment mobilisation through a combination of robustness, mobility, and ability to re-position themselves within the substratum. As such, they are tolerant of disturbed environments and can recover quickly.

It is unlikely that the hard substrata would be affected by disturbance not directly on top of the habitats and the rocky areas on the two northerly beaches are surrounded by natural

buffer habitats of scoured rock biotopes. The lower shore *Fucus serratus* on eulittoral boulders biotope correlates with the intertidal boulder habitat listed in the Scottish Biodiversity List (SBL). Some hard substrata, especially to the north and south of Landfall F but also, the southern ends of each of the northerly beaches, included rockpools and underboulder communities and may constitute a SBL priority habitat. Landfall F is already subject to disturbance adjacent to rocky areas in the form of artificially placed rock armour, some of which may have collapsed on to natural rock, and outfalls from industry. It is unlikely that cable laying activities in the central sandy area would have long-term impacts on the rockpool habitats to the north and south.

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# Appendix 1 Survey Core and Quadrat Sample Locations

| Original label | Label used on survey | Sampling Type | Date | Time | Latitude | Longitude |
|---|---|---|---|---|---|---|
| D1 | D1U | Core | 18/07/2023 | 05:50 | 57.567653 | -1.819880 |
| D2 | D1M | Core | 18/07/2023 | 06:01 | 57.567722 | -1.818901 |
| D3 | D1L | Core | 18/07/2023 | 06:09 | 57.567789 | -1.818046 |
| D6 | D2L | Core | 18/07/2023 | 06:21 | 57.563999 | -1.814854 |
| D5 | D2M | Core | 18/07/2023 | 06:28 | 57.563825 | -1.815636 |
| D4 | D2U | Core | 18/07/2023 | 06:36 | 57.563689 | -1.816304 |
| D9 | D3L | Core | 18/07/2023 | 06:52 | 57.560374 | -1.810088 |
| D8 | D3M | Core | 18/07/2023 | 06:58 | 57.560052 | -1.810770 |
| D7 | D3U | Core | 18/07/2023 | 07:04 | 57.559754 | -1.811574 |
| D12 | D4L | Core | 18/07/2023 | 07:23 | 57.557529 | -1.805110 |
| D11 | D4M | Core | 18/07/2023 | 07:47 | 57.557278 | -1.805426 |
| D10 | D4U | Core | 18/07/2023 | 07:59 | 57.556828 | -1.805998 |
| E1 | E1U | Core | 17/07/2023 | 07:49 | 57.542268 | -1.803298 |
| E2 | E1M | Core | 17/07/2023 | 07:40 | 57.541991 | -1.802523 |
| E3 | E1L | Core | 17/07/2023 | 07:17 | 57.541813 | -1.802119 |
| E7 | E2U | Core | 17/07/2023 | 06:51 | 57.536842 | -1.806754 |
| E8 | E2M | Core | 17/07/2023 | 06:42 | 57.536813 | -1.805923 |
| E9 | E2L | Core | 17/07/2023 | 06:35 | 57.536819 | -1.805083 |
| E10 | E3U | Core | 17/07/2023 | 06:10 | 57.531244 | -1.806999 |
| E12 | E3M | Core | 17/07/2023 | 06:00 | 57.531152 | -1.806424 |
| E11 | E3L | Core | 17/07/2023 | 05:54 | 57.531261 | -1.805754 |
| E4 | E4U | Core | 17/07/2023 | 05:11 | 57.525781 | -1.803956 |
| E5 | E4M | Core | 17/07/2023 | 05:25 | 57.525854 | -1.803312 |
| E6 | E4L | Core | 17/07/2023 | 05:36 | 57.526023 | -1.802853 |

| | | | | | | |
|---|---|---|---|---|---|---|
| E additional | WP 91 | Core | 17/07/2023 | 07:59 | 57.541669 | -1.803794 |
| E additional | WP 121 | Core | 17/07/2023 | 08:35 | 57.539205 | -1.806163 |
| F1 | F1U | Core | 19/07/2023 | 06:56 | 57.484391 | -1.796086 |
| F2 | F1M | Core | 19/07/2023 | 07:06 | 57.484435 | -1.795471 |
| F3 | F1L | Core | 19/07/2023 | 07:16 | 57.484431 | -1.795000 |
| F4 | F2U | Quadrat | 16/07/2023 | 16:31 | 57.481090 | -1.791471 |
| F5 | F2M | Quadrat | 16/07/2023 | 16:51 | 57.481272 | -1.791290 |
| F6 | F2L | Quadrat | 16/07/2023 | 17:12 | 57.481423 | -1.791155 |
| F7 | F3U | Quadrat | 16/07/2023 | 18:25 | 57.478344 | -1.785235 |
| F8 | F3M | Quadrat | 16/07/2023 | 18:09 | 57.478491 | -1.784724 |
| F9 | F3L | Quadrat | 16/07/2023 | 18:15 | 57.478595 | -1.784575 |

# Appendix 2 Raw PSA and Benthic Data

Please see Excel file attached within this document

## Appendix 3 Photographs of each core sample: Landfall D

| | | |
|---|---|---|
|  |  |  |
| D1U | D1M | D1L |
|  |  |  |
| D2U | D2M | D2L |
|  |  |  |
| D3U | D3M | D3L |
|  |  |  |
| D4U | D4M | D4L |

# Appendix 4 Photographs of each core sample: Landfall E

| | | |
|---|---|---|
|  |  |  |
| **E1U** | **E1M** | **E1L** |
|  |  |  |
| **E2U** | **E2M** | **E2L** |
|  |  |  |
| **E3U** | **E3M** | **E3L** |
|  |  |  |
| **E4U** | **E4M** | **E4L** |

# Appendix 5 Photographs of each core sample: Landfall F

| | | |
|---|---|---|
|  |   |  |
| **F1U** | **F1M** | **F1L** |

# Appendix 6 Photographs of each quadrat sample: Landfall F

| | | |
|---|---|---|
|  |  |  |
| F1U | F1M | F1L |
|  |  |  |
| F2U | F2M | F2L |
|  |  |  |
| F3U | F3M | F3L |

# Appendix 7 Photographs of species found during surveys

| | | |
|---|---|---|
|  |  |  |
| ***Arenicola*** **casts at Landfall D** | ***Littorina littorea*** **and** ***Arenicola*** **cast at Landfall D** | ***Fucus***, ***Ulva*** **and** ***Rhodothamniella*** **at Landfall D** |
|  |  |  |
| ***Semibalanus balanoides*** **and** ***Ulva intestinalis*** **at Landfall E** | ***Porphyra***, ***Ulva*** **and** ***Fucus*** **at Landfall E** | ***Actinia equina*** **at Landfall E** |
|  |  |  |
| ***Patella vulgata***, ***Wahlenbergiella mucosa*** **and barnacles at Landfall F** | ***Ascophyllum nodosum*** **at Landfall F** | ***Porphyra*** **at Landfall F** |
|  |  |  |
| ***Fucus serratus*** **at Landfall F** | ***Porphyra*** **and** ***Ulva*** **at Landfall F** | ***Nucella lapillus*** **and barnacles at Landfall F** |

# Appendix 8 Photographs of transects from lower shore samples

| Landfall D: Scotstown Beach | Landfall E: Lunderton Beach | Landfall F: Sandford Bay |
|---|---|---|
|  |  |  |
| **D1L** | **E1L** | **F1L** |
|  |  |  |
| **D2L** | **E2L** | **F2M** |
|  |  |  |
| **D3L** | **E3L** | **Shore SE of F3 transcet** |
|  |  | |
| **D4L** | **E4L** | |

MarramWind