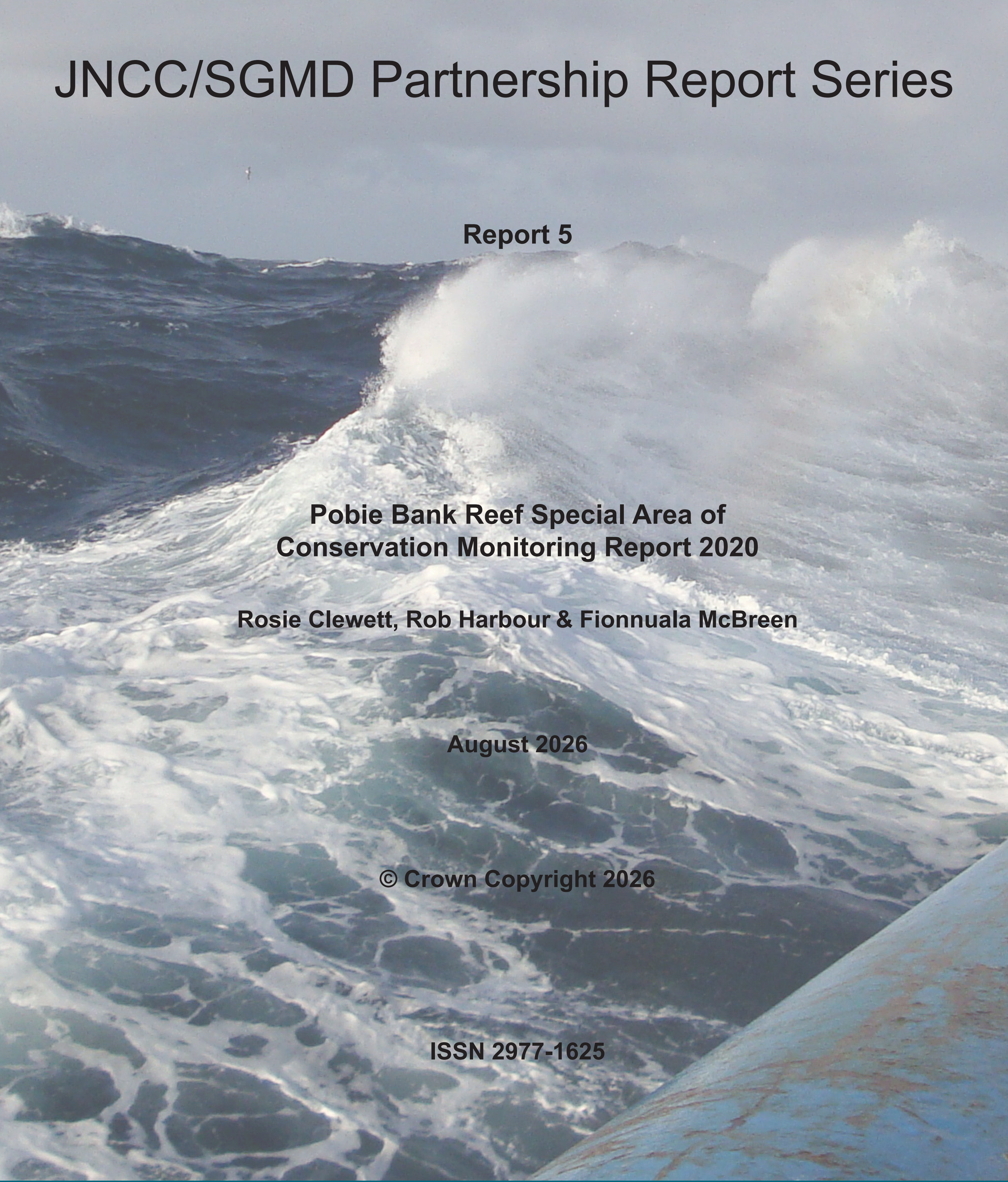

JNCC/SGMD Partnership Report Series

Report 5

Pobie Bank Reef Special Area of Conservation Monitoring Report 2020

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Evidence Quality Assurance:
This document is compliant with JNCC's Evidence Quality Assurance Policy.

Summary

The Joint Nature Conservation Committee (JNCC) and the Marine Directorate of the Scottish Government (formerly Marine Scotland Science, MSS) undertook an offshore seabed survey of Pobie Bank Reef SAC on the Marine Research Vessel *Scotia* from the 22 August to 2 September 2020. This survey aimed to gather data which would allow the Scottish Government to fulfil its obligations to Marine Protected Area assessment and reporting.

Still and video imagery were collected at 84 stations across the 966 km^2 site. Multibeam and sidescan sonar were used in five high priority areas, parts of the site which previously had no bathymetric data available. The imagery was annotated for epifauna, biotopes and conditions denoting the presence of Annex I reef. Epifaunal communities were analysed at 54 out of 84 stations across the site, where there was a sufficient volume of imagery available.

A summary of the outcomes of each report objective is given in Table 1 below.

Table 1. Summary of report objectives and outcomes from analysis.

Objective	Outcome
Describe the extent and distribution of the Annex I reef	Out of 84 stations surveyed for Annex I reef, 39 contained the stony reef or a mixture of stony and bedrock reef and a further 8 stations contained bedrock reef only. These stations are distributed throughout the site but vary in the proportion of reef coverage. The remaining substrate consisted of circalittoral coarse sediment.
Describe the characteristic biological communities of the Annex I reef and other habitats	Epifaunal communities at the site were broadly split between hard and soft substrata. Taxa most strongly associated with the hard substrate were *Caryophillia smithii* (Devonshire Cup Corals), *Omalosecosa ramulosa* (Bryozoan) and Brachiopoda. Other taxa present in the rocky reef and bedrock were Galatheidae (Squat lobster family), *Ophiothrix fragilis* (Brittlestar species), Caridea (Caridean shrimp) and barnacles. Coarse sediments were associated with taxa such as Serpulidae tube worms, *Lanice conchilega* (Sand Mason Worm) and Paguridae crabs. *Adamsia palliata* (Cloak Anemone) and *Ophiura albida* (Serpent's Table Brittlestar) were also found to explain a high proportion of variation in epifaunal assemblages across the site due to their strong association with coarse sediment.
Present information relating to supporting processes which are known to influence the designated and additional habitat and species features	The primary environmental drivers of epifaunal variation at PBR were identified to be the proportion of cobbles and bedrock in the substrate, further impacted by hydrodynamic exposure (effect of currents on the seabed).
Present evidence relating to non-indigenous species	No invasive non-native species were recorded during this survey.

Objective	Outcome
Present evidence relating to anthropogenic activity	Some damage to erect reef species was recorded which may be attributable to fishing activities. Presence of marine litter was noted at eight stations, including entangled fishing line.
Provide practical recommendations for appropriate future monitoring approaches for the designated features	The primary recommendations from this report are listed below. • Taxa-specific enumeration methods should be determined prior to the commencement of image annotation and should remain consistent per taxonomic group. • Future surveys should use data from previous visits to Pobie Bank Reef SAC to re-calculate the required sample unit size of still imagery and ensure a sufficient volume of imagery is collected for robust analysis to take place. • Future surveys should include the stations to the north and west of the site which were not visited in 2020, particularly as some of these stations are excluded from upcoming management measures (Scottish Government, 2025). • A folder of characterising imagery should be compiled during the annotation process which can be used for future communications, showcasing key or notable taxa, habitats and evidence of anthropogenic activity. • Further work should investigate the potential relationships between hydrodynamic conditions and nutrient availability using a CTD.

Contents

List of figures

List of tables

1. Introduction

JNCC is the Statutory Nature Conservation Body (SNCB) for UK offshore waters, whose responsibilities include monitoring Marine Protected Areas (MPAs). JNCC have produced this report to provide information allowing the Scottish Government to fulfil its obligations in relation to MPA assessment and reporting.

This monitoring report explores data acquired from the first dedicated monitoring survey of Pobie Bank Reef MPA. It will form the initial point in a Type 1 (sentinel) monitoring time series against which the feature condition can be assessed in future. This survey took place between the 22 August and 7 September 2020 on the MRV *Scotia*, cruise 1220S. The specific aims of the report are discussed in more detail in Section 1.4.

This report does not aim to assess the condition of the designated features. SNCBs use evidence from MPA monitoring reports in conjunction with other available evidence (e.g. activities, pressures, historical data, survey data collected from other organisations or collected to address different drivers) to make assessments on the condition of designated features within an MPA.

1.1. Site overview

Pobie Bank Reef (PBR) MPA is an offshore Special Area of Conservation (SAC) located in the northern North Sea, 20 km east of Shetland (Figure 1). The site lies across the 12 nm boundary, with conservation advice jointly delivered by JNCC and NatureScot. It was first designated as a SAC in 2017, for its designated Annex I reef. The depth of the seabed ranges between approximately 70 m and 120 m and covers an area of 966 km^2.

The reef at PBR is a mixture of bedrock and stony reef, topographically distinct from the seafloor and dominated by epifaunal and mobile species. It is located on a bank of metamorphic and sedimentary rocks and is covered by a patchy veneer of sediment, ranging from sandy gravels to slightly gravelly sands. In the central section of the reef, large, rugged bedrocks outcrop from areas of sand, forming the most topographically complex area. These outcrops are often surrounded by large boulders and cobbles in a sandy matrix. Towards the north and south of the reef, bedrock outcrops are smoother and integrated with extensive areas of stony reef. The bedrock and boulders provide reef habitat for a variety of species.

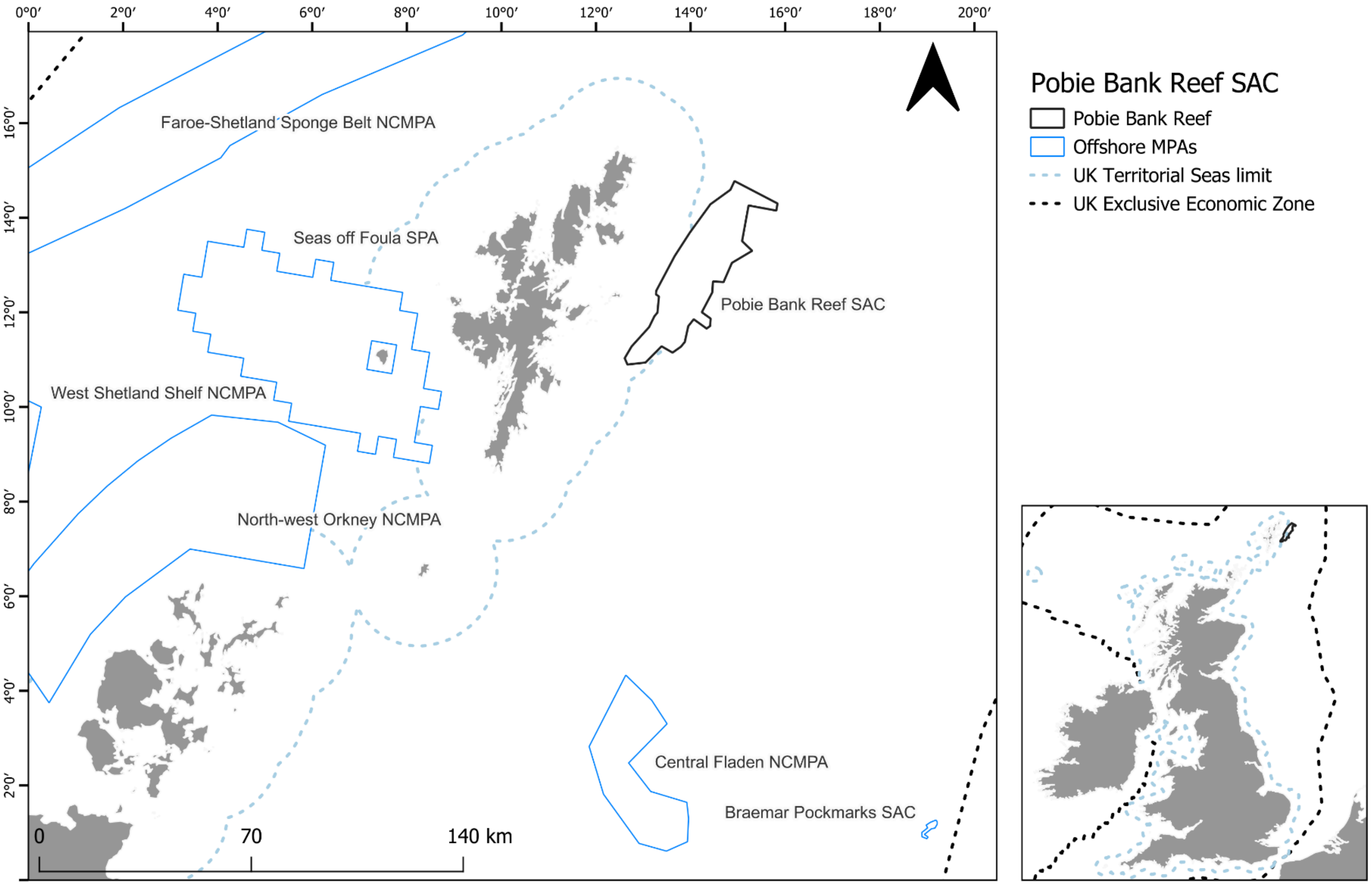

Figure 1. Location of the Pobie Bank Reef MPA in the context of Marine Protected Areas proximal to the site.

1.2. Annex I reef

The designated feature for Pobie Bank Reef MPA is Annex I stony and bedrock reef, defined below.

Reefs are formed by biogenic concretions or non-biogenic substrata, which arise from the seafloor and are topographically distinct from their surroundings (European Commission 2015). They are generally found in the subtidal zone but may extend in a broken transition into the intertidal zone. Annex I reefs include biogenic, bedrock and stony reefs. The UK has a greater range and extent of rocky reefs than biogenic reefs, the former being extremely variable in the structure and the communities they support (Brown *et al.* 1997). They range from vertical rock walls to horizontal ledges, sloping or flat bed rock, broken rock, boulder fields, and aggregations of cobbles.

A variety of invertebrates can inhabit rocky reefs, including sponges, corals and sea squirts, which attach to the rock surface. Mobile species, such as fish, lobsters and crustaceans, may also use rocky reefs for shelter. Both types of rocky reefs: bedrock reefs and stony reefs, are protected features within PBR.

1.2.1. Bedrock reef

Bedrock reef occurs where the bedrock that underlies surface sediments on the seafloor arises from the surrounding seabed, creating a habitat that is colonised by many different marine animals and plants. Bedrock is consolidated rock and can be composed of most rock types (granite, limestone, sandstone, etc.). The feature can be varied in shape, forming pinnacles, pavement, ridges or banks, and may also have a non-continuous mobile veneer of sediment (Johnston, Turnbull & Tasker 2002).

1.2.2. Stony reef

Stony reef occurs where 10% or more of the seabed substratum are composed of particles greater than 64 mm across (i.e. cobbles and boulders; European Commission 2015). The remaining supporting ‘matrix’ could be of smaller sized material. The reef may be consistent in its coverage, or it may form patches with intervening areas of finer sediment. Epifaunal species dominate biological cover. Stony reef should be topographically distinct from the surrounding sea floor with a minimum area of 25 m^2 (this also applies to the total area of a patchy reef) (Irving 2009).

1.3. Existing data and habitat maps

Three surveys of Pobie Bank Reef MPA had been carried out prior to the survey by JNCC and the Scottish Government’s Marine Directorate (previously Marine Scotland Science) in 2020. These surveys were designed to achieve various objectives, collecting multibeam, sidescan, infaunal and epifaunal data. A full list of these surveys, samples and data is available in the ‘Monitoring and Evidence’ section of the Pobie Bank Reef MPA Site Information Centre (Pobie Bank Reef MPA 2024) and is summarised below. The locations of bathymetry and imagery data collected from these surveys are displayed in Figure 2.

1.3.1. 2005 / 2006 - Strategic Environmental Assessment (SEA 5 and SEA SAC) surveys

These surveys were commissioned by the former Department of Trade and Industry in collaboration with JNCC (Strategic Environmental Assessment (SEA) Surveys 2005 and 2006, 2017). They acquired multibeam, sidescan sonar and ground-truthing data (seabed imagery and biological/sediment samples). Although full coverage multibeam and sidescan data was not present for all locations where potential Annex I reef was indicated, the available data provided a good indication of the nature of Annex I reef habitat present within Pobie Bank Reef MPA.

1.3.2. 2013 - JNCC and Scottish Government's Marine Directorate (formerly Marine Scotland Science) survey

This survey aimed to gather high quality evidence to characterise and describe seabed habitats and communities within PBR, to improve understanding of habitat distribution and sensitivity across the site and facilitate the discussion of fisheries management measures with industry (Parry & Robertson 2019). This survey collected stills, video, sediment and macrofauna, multibeam and side scan data. Habitat maps were produced for the areas covered by acoustic data.

A habitat map was produced by combining SEA5 and SEA SAC survey data with other predictive maps to produce an Annex I reef and confidence map for PBR (visible in Figure 5). The location of acoustic and imagery data collected from these surveys is illustrated in Figure 2.

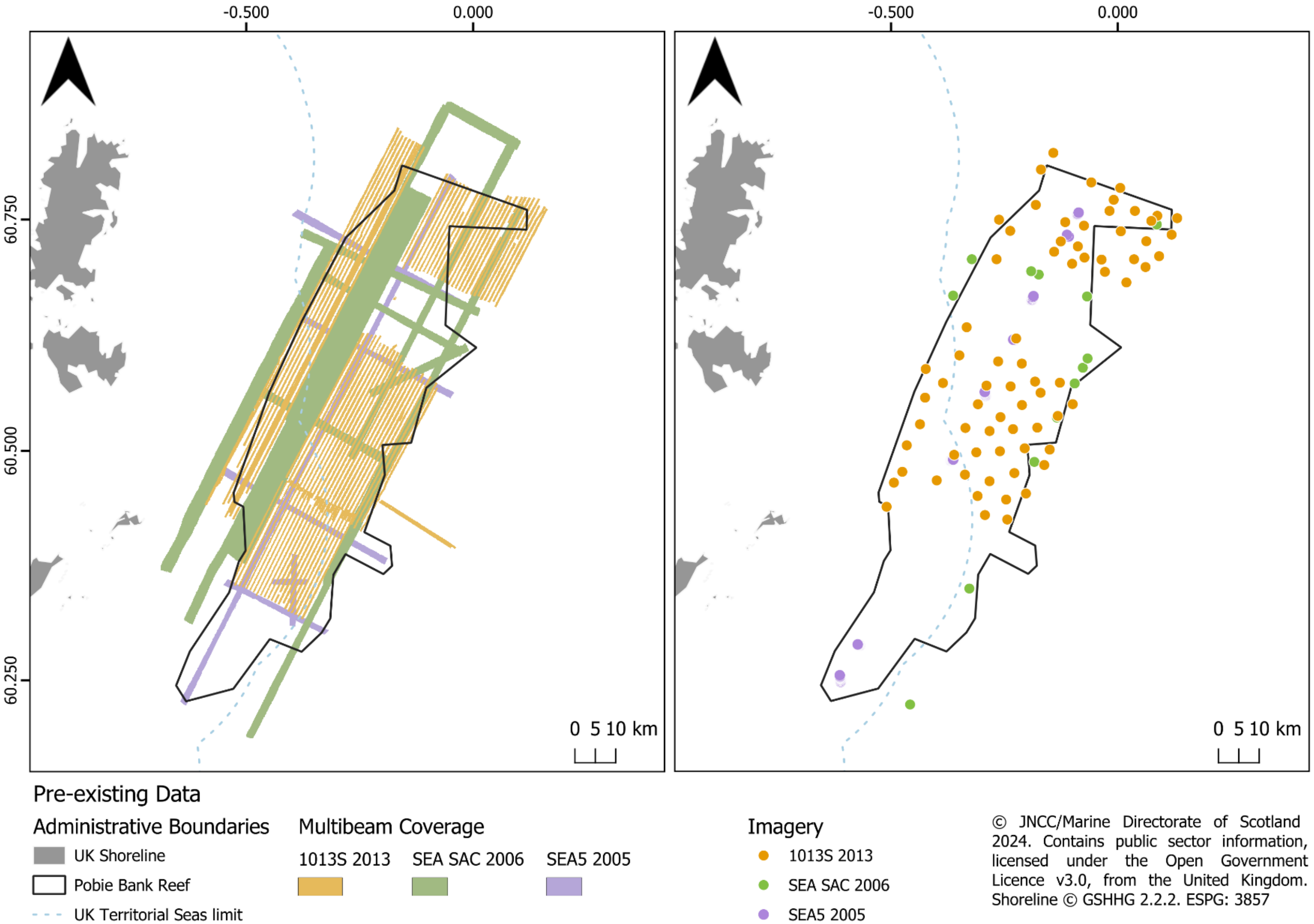

Figure 2. Pre-existing bathymetry and imagery data collected from 1013S, SEA5 2003 and SEA SAC 2006 surveys. Imagery 'dots' may signify a station (1013S, SEA SAC 2006), or individual image (SEA5).

1.4. Aims and objectives

1.4.1. Conservation objectives

High-level, site-specific conservation objectives serve as a benchmark against which to monitor and assess the efficacy of management measures in protecting designated features within MPAs.

The conservation objectives for Annex I reef at Pobie Bank Reef MPA are:

> Subject to natural change, maintain or restore the reef in/to favourable condition, such that:
>
> - the natural environmental quality and processes supporting the habitat
> - the extent of the habitat on site
> - the physical structure, community structure, function, diversity and distribution of the habitat and typical species representative of the reef in the Northern North Sea regional sea
>
> are maintained or restored, thereby ensuring the integrity of the site and making an appropriate contribution to favourable conservation status of the Annex I habitats. *(Offshore and Inshore Special Area of Conservation Pobie Bank Reef Conservation Objectives and Advice on Operations 2013)*

1.4.2. Report aims and objectives

The primary aim of this monitoring report is to explore and describe the attributes of the features within PBR to enable future assessments of feature condition as part of a separate process (i.e. to determine whether conservation objectives have been achieved).

The results presented will be used to develop recommendations for future monitoring, including the operational testing of specific metrics which may indicate whether the condition of the features has been conserved, improved or declined. The specific objectives of this monitoring report and the associated outputs are provided in Table 2.

Table 2. Report objectives and outputs.

Objective	Feature attributes	Sub-attributes	Outputs
1. Describe the extent and distribution of the Annex I reef	Extent and distribution	-	Point map showing presence and sub-type of reef at each station
2. Describe the characteristic biological communities of the Annex I reef and other habitats	Structure and function (biological and physical)	Presence and spatial distribution of biological communities Presence and abundance of key structural and influential species Species composition of component communities	Multivariate and univariate analysis of data nMDS plots Biotope point map (include 2013 data) Identify key and structural species Identify potential indicator species
3. Present information relating to supporting processes which are known to influence the designated and additional habitat and species features	Supporting processes	Substrate Hydrodynamic exposure Surface and sub-surface abrasion (swept area ratio)	Identify key environmental influences on epifaunal assemblage DistLM Bio-Env
4. Present evidence relating to non-indigenous species	Anthropogenic impact	INNS (invasive and non-native species)	Point map of observations (if any)
5. Present evidence relating to anthropogenic activity	Anthropogenic impact	-	Description of activity (if any) Point map of litter occurrence across the site

Objective	Feature attributes	Sub-attributes	Outputs
6. Provide practical recommendations for appropriate future monitoring approaches for the designated features (e.g. metric selection, survey design, data collection approaches) with a discussion of their requirements.	-	-	Set of recommendations regarding: • methods for calculation of sample size in future surveys; • future monitoring at PBR; • and general recommendations on analysis and interpretation.

2. Methods

2.1. Survey design

The 1220S survey to Pobie Bank Reef MPA was designed to acquire a robust initial sentinel monitoring baseline dataset of the Annex I reefs. This report focuses on the analysis of the seabed imagery data collected during the survey.

Power analysis of existing imagery data from 2013 was used to determine the number of required drop camera stations. The analysis indicated that 70 stations would be required to detect 20% change in species richness with a statistical power of 0.8 on Annex I reef. Given the uncertainty in the extent and distribution of the Annex I reef feature, 100 stations were distributed in an equidistant triangular grid across the site (Figure 3). Approximately 70% of the stations were expected to intersect with the Annex I reef itself based on existing habitat maps. In addition, an increased number of images were taken per transect than on the 2013 survey, with an image taken once every 15-20 seconds vs one per minute as in 2013. This data will be used to address report objectives one, two, four and five (Table 2).

Acoustic data was also collected during the survey to inform the creation of a new habitat map for Pobie Bank Reef MPA. A further JNCC/Marine Directorate joint monitoring survey to PBR was conducted in 2023 (Tangye & Stirling 2024) which will allow the combination of multibeam and sidescan data from the 2020 and 2023 surveys to produce one habitat map which will be published in a separate report.

More detailed information on survey design is available in the Cruise Report (Albrecht & Stirling 2021).

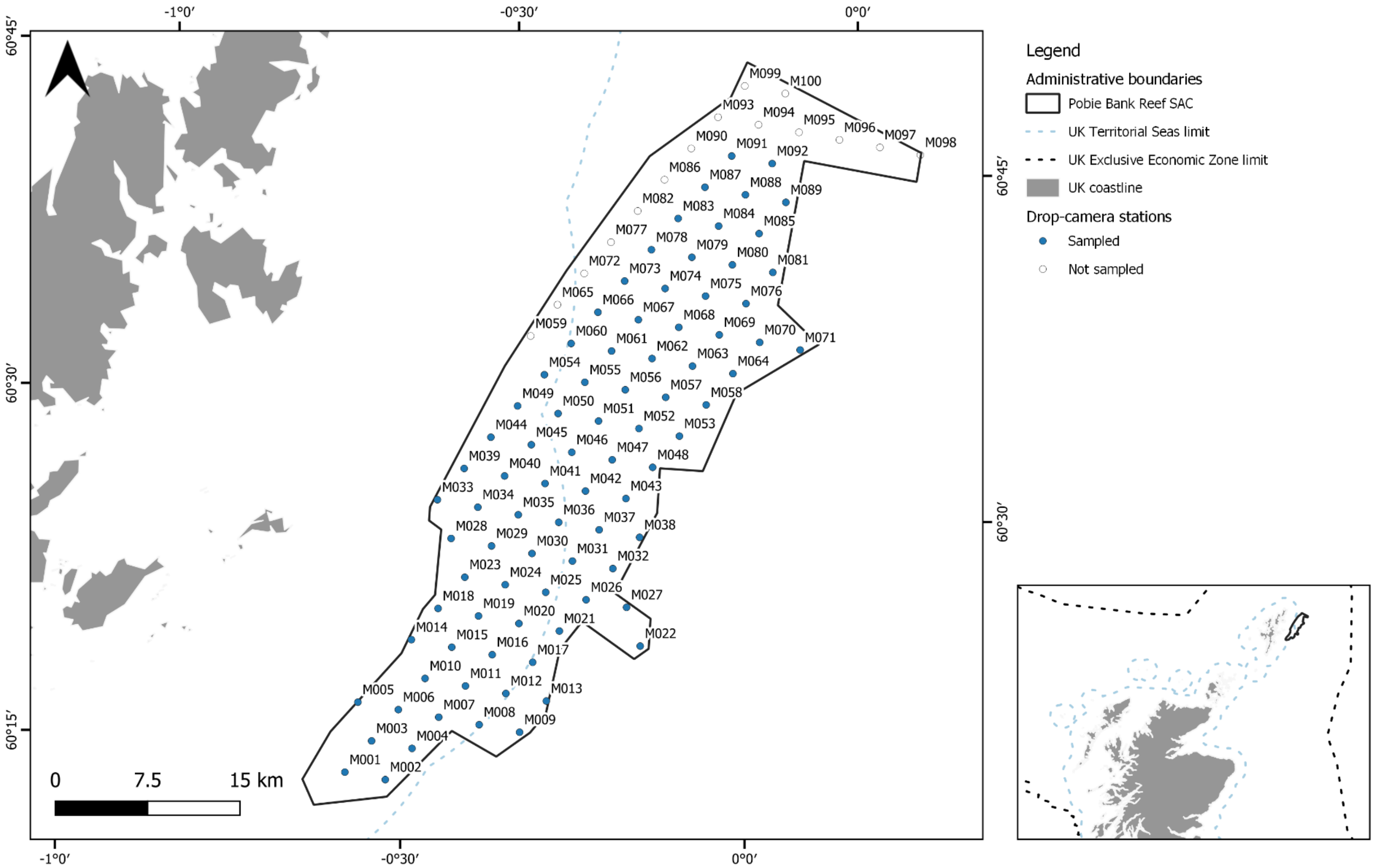

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Figure 3. Location of successful drop camera stations completed at Pobie Bank Reef MPA in 2020.

2.2. Data acquisition

2.2.1. Acoustic data

Depth values were extracted from the best available bathymetry data, either from groundtruthed site multibeam (Parry & Robertson 2019; Albrecht & Stirling 2021) or modelled EMODnet bathymetry layer if multibeam was not available (Vasquez *et al*. 2021).

2.2.2. Imagery

During the survey, only 84 drop camera stations were visited out of the target number of 100 due to poor weather conditions. At each station, video was recorded throughout the 150 m transect; still images were captured approximately every 15–20 seconds when all four of the listed conditions were true:

1. The seabed was clearly visible
2. The camera was at the correct altitude (1 m above the seabed) and in focus
3. The flash had an opportunity to charge
4. The camera's field of view had changed since the last image

Opportunistic camera (OppCam) was used at three out of five ground truthing stations (GT01, GT04 and GT05) to improve understanding of a seabed feature seen in acoustic data within Box C. These images were not included in the epifaunal analysis.

2.2.3. Other explanatory variables

A selection of environmental measurements were used as potential explanatory variables in the multivariate analysis. The definition for and origin of each of these data is described in Table 3.

Table 3. Explanatory variables used in multivariate community analyses, their definitions and data sources.

Explanatory variables	Definition	Source
Depth (m)	Depth from the surface of the water to the seabed	Depth extracted from best and most up-to-date acoustic data (1220S, 1013S) or from EMODnet bathymetry layer

Explanatory variables	Definition	Source
Substrate (% cover in a still image)	• Bedrock • Boulders (over 1024 mm) • Boulders (512 to 1024 mm) • Boulders (256 to 512 mm) • Cobbles (64 to 256 mm) • Pebbles (4 mm to 64 mm) • Shells (empty) • Granule (2 mm to 4 mm) • Shell (2 mm to 4 mm) • Sand (0.063 mm to 2 mm) • Biogenic rubble The following categories were not included as they were absent from all images. • Shell (Live Modiolus) • Mud (less than 0.063 mm) • Dead Maerl • Live Maerl • Artificial Reef • Biogenic Reef	Estimate of substrate percentage cover recorded in still images collected on the 1220S survey
Total surface abrasion swept area ratio (2016 – 2020)	Surface abrasion is the damage to seabed surface features from the parts of fishing gear that are in contact with the seabed (Tillin & Tyler-Waters 2010), The swept area ratio (SAR) is the equivalent times the area of the grid cell the station is in has been swept by fishing gear (Church *et al.* 2016).	ICES Fishing Intensity layers (ICES 2021)
Sub-surface abrasion swept area ratio (2016 – 2020).	Sub-surface abrasion is damage to seabed surface and penetration from the parts of fishing gear that are in contact with the seabed (Tillin, Hull & Tyler-Walters 2010). The swept area ratio (SAR) is the is the equivalent times the area of the grid cell the station is in has been swept by fishing gear (Church *et al.* 2016).	ICES Fishing Intensity layers (ICES 2021)
Peak seabed kinetic energy due to waves (ke100w)	Peak seabed kinetic energy (KE) caused by waves was calculated using peak seabed water velocities during a wave period (U_b), using the formula KE = ½ $\rho_w U_b^2$, where ρ is the density of seawater.	(West, Swift & Bell 2010)

Explanatory variables	Definition	Source
Peak seabed kinetic energy due to currents (ke100)	Peak seabed kinetic energy (KE) caused by waves was calculated using peak tidal current speeds (U_{c} in m/s), using the formula KE = ½ $\rho_w U_c^2$, where ρ is the density of seawater.	(West, Swift & Bell 2010)

2.3. Data preparation and statistical analysis

2.3.1. Extent and distribution of Annex I reef

Video transects were analysed by marine ecologists at Seastar Survey Ltd, where transects were split into segments delineating changes in either broadscale habitat (BSH) or Annex I reef sub-type. Each segment was assigned to one of three categories: 'not reef', 'bedrock reef' and 'potential stony reef'. The 'not reef' category was assigned to a segment where there was no, or less than, 10% hard substrate visible; 'potential stony' when seabed composition was around or above 10% cobble or boulder as described in Irving (2009). Following the Irving (2009) stony reef designation criteria, elevation and composition were also assigned to video segments. Further checks of the video were completed where the video segment was labelled 'potential stony' and reef composition was deemed 'low' to make a final judgement. Extent was accounted for during the annotation process as all segments have a minimum required area of 25 m^2.

The mapping of Annex I reef distribution was completed in QGIS v3.34, illustrating the presence of stony reef and bedrock at stations across the site. The duration of video assigned to each sub-type per station was calculated and displayed in the figure as a proportion of the total transect duration. Stations were represented by one reef subtype only: if a mixture of reef subtypes were present within the station, it was listed as 'Annex I stony reef x bedrock', with reef subtypes superseding any segments which were classed as 'not reef'.

2.3.2. Annex I reef community analysis

2.3.2.1. Imagery annotation

Biological and environmental data were extracted from the drop camera video and stills following the North East Atlantic Marine Biological Analytical Quality Control (NMBAQC) guidelines (Turner *et al.* 2016). Still imagery data was used to identify and enumerate taxonomic data, while video imagery was analysed for broad-scale habitat (BSH), video quality, elevation and composition by Seastar Survey Ltd following guidance further detailed below.

- Images were classified into NMBAQC quality categories
- Percentage cover of substrate types was recorded per image
- Epibiota were identified and tagged using a nested CATAMI naming tree (Althaus *et al.* 2015) in BIIGLE, recording species to the lowest possible taxonomic level within the appropriate morphological category
- Solitary and erect taxa were given point annotations constituting count data, and colonial, encrusting or massive taxa were either delineated with polygons or estimated by eye constituting percentage cover

2.3.2.2. Data extraction and truncation

Following the data extraction from the images as described above, taxonomic identification and enumeration data were truncated according to the NMBAQC Epibiota Identification Protocol (Turner *et al.* 2016). As much taxonomic diversity was retained as possible, however records were removed or merged with other entries as required for reasons detailed below. Full details of the biological truncation protocol are available in Appendix 2.

- Images were filtered according to quality ('good' or 'excellent' only), and field of view (FOV) (between 0.5 m^2 and 1.5 m^2 only)
- Fish species were removed
- Taxa with insufficient or no taxonomic resolution were removed (e.g. 'biota' or 'indetermined ID')
- Evidence of presence other than the organism itself was removed (e.g. eggs and burrows)

2.3.2.3. Sample unit calculation

Imagery stations are naturally varied in the number of usable images they yield and consequently require standardisation to a sample unit to be comparable. The size of the optimal sample unit was calculated using the sample coverage stopping algorithm (covstop,R, Chao & Jost 2012). As individual stations did not contain enough data to run the algorithm independently, images from each station were pooled with those from its two nearest neighbouring stations for the purpose of calculating the sample unit size. The nearest neighbour approach was used to minimise the influence of varying environmental conditions and biological communities on the sample size.

Initial attempts aimed to determine the number of images required per station to achieve an ideal sample coverage of 90% of the theoretical community present based on mathematically modelled data extrapolation. A level of 90% sample coverage is generally considered a good compromise between data accuracy and sampling effort (Montes *et al.* 2021). By lowering the coverage there is increased chance of missing the observation of unique benthic communities or artificially identifying communities that are not actually present. To ensure a conservative approach, the highest number of images required across all station pools was selected as the standard for all stations. This analysis indicated that 48 images were needed to reach 90% coverage. However, none of the stations at PBR had this number of images available.

To address this limitation, the target sample coverage was reduced in 10% increments. A coverage level of 70% was ultimately selected, requiring 14 images per station; an achievable threshold which also preserved representation across a larger number of stations. Each station was therefore standardised to 14 images, selected through random sampling without replacement. A table is available in Appendix 3 displaying the numbers of images required and stations with the required capacity for each level of sample coverage. The data were not pooled between stations for the final analysis.

These standardised stations were used as samples for epifaunal community analysis. Of the 84 stations visited, 83 had complete epifaunal and corresponding biotope data. Of these, 29 had fewer than 14 usable images and were therefore excluded, leaving 54 available for subsequent analysis.

2.3.3. Statistical analysis

Statistical analyses were conducted to assess how and why species assemblages may vary across the site. To do this, the truncated and filtered data was used.

Data cleaning and organisation was completed using R version 4.3.2 (R Core Team 2023). In PRIMER-e (Clarke & Gorley 2015), the count and percentage cover data were combined, averaged per sample unit, fourth root transformed and standardised per sample. Combining methods of enumeration has been deemed as an appropriate method to represent whole communities (Anderson 2024). Fourth-root transformation was chosen after consideration of the shade plots to not over-weight any highly dominant species such as the Devonshire Cup Coral, *Caryophyllia smithii*.

2.3.3.1. Univariate analysis

To calculate indices of univariate diversity, count and cover data were combined. Data within each station sample unit were summed and no further transformations applied. The 'DIVERSE' tool in PRIMER was used to calculate species richness, abundance, Pielou's evenness index and Shannon diversity (Table 4).

Table 4. Table of univariate indices used in analysis and how to interpret their values.

Univariate index	Formula	Definition	Interpretation
Species richness	S	Number of species recorded	Highly dependent on sampling effort.
Abundance	N	Number of individual records	Highly dependent on sampling effort.
Pielou's evenness index	$J' = H'/\text{Log}(S)$	How even or dominant species are within a community	Range 0 – 1, 1 being maximum evenness.
Shannon diversity index	$H' = -\text{SUM}(P_i*\ln(P_i))$	Diversity index incorporating richness and evenness	Range 0 – H_{max}, higher values indicate greater diversity.

2.3.3.2. Multivariate analysis

To identify and separate distinct epifaunal communities, a Bray-Curtis resemblance matrix was calculated based on combined count and percentage cover data, pooled and transformed as previously described. Hierarchical agglomerative clustering was performed, and the SIMPROF routine was used to determine statistically distinct epifaunal groupings at a 5% significance level (Figure 4). An nMDS plot was created to represent the similarity of samples. A suite of multivariate analyses were performed on this data, which are described in Table 5.

Table 5. Epifaunal multivariate analysis conducted using the statistical software PRIMER v7.

Multivariate routine stages	Application
Hierarchical agglomerative clustering	Used in conjunction with SIMPROF to look for identifiable clusters in the dataset (i.e. any sub cluster could be randomly permuted).
Similarity profiles (SIMPROF)	To determine if the dataset has a structure distinct from that derived by random permutation.
Non-metric multidimensional scaling (nMDS)	To explore the relationships and differences between samples.
Similarity percentage (SIMPER)	To identify characterising taxa in each cluster group.
Biota matching (BVSTEP)	To determine the smallest subset of taxa which explains the variation in the biological assemblage.
Distance-based linear model (DistLM)	To determine how much biological variance is explained by environmental variables (depth, sediment type).
BEST (Bio-Env)	To determine an optimal subset of environmental variables which best matches the biotic pattern.

Environmental variables were transformed and normalised before running the DistLM. Surface and sub-surface abrasion variables were transformed using the natural logarithm in the formula LOG(2+y), while sediment type variables were square root transformed.

DistLM was used to identify the most parsimonious model containing the environmental variables responsible for driving variation in the epifaunal groupings, using three complementary approaches: Best with Akaike Information Criterion (AIC), best with Bayesian Information Criterion (BIC), and forward selection by R^2.

While a 'best' selection procedure examines the value of the selection criterion for every possible combination of the predictor variables in the model, a 'forward' selection procedure adds one variable at a time which most improves the value of the chosen selection criterion. The AIC (Akaike 1973) and BIC (Schwarz 1978) selection criteria are values which decrease as the maximum likelihood of the model increases but incur 'penalties' for each additional predictor variable included, increasing the value. BIC has a stronger penalty for each addition, meaning that the use of BIC will select models with fewer variables included. Lower values of AIC and BIC indicate a preferred model. The R^2 value indicates the proportion of variation explained by the model and contains no penalty for increased model complexity, meaning R^2 always increases as more variables are added to the model. However, R^2 can be used to conduct marginal tests quantifying the additional variation explained by a predictor variable when it is added to the model. Comparisons with the 'Adjusted R^2' criterion yielded the highly similar results to R^2, and R^2 was used subsequently for exploratory purposes.

A Bio-Env test was also run on the transformed environmental data to find the smallest subset of environmental variables which match the pattern in the epifaunal assemblage. This was run on a Euclidean distance matrix using a Spearman rank correlation method.

A BEST analysis with BVSTEP methodology was used to find the smallest characterising subset of fauna which explains the variation in epifaunal assemblages. This was run based on the Spearman rank correlation of the Bray-Curtis resemblance matrix, with six randomised starting variables and 25 restarts.

A one-way SIMPER analysis was conducted to determine the species-level contributions to the grouping of the samples. Only species contributing over 70% to the similarity of the group were considered in the results. This test was initially performed on SIMPROF groups; however, this resulted in a high number of groups with high inter-group similarity. To investigate the fauna driving difference between large groupings of stations, the dendrogram was sliced at 40% similarity, resulting in three more meaningful clusters, instead of the 14 identified through SIMPROF.

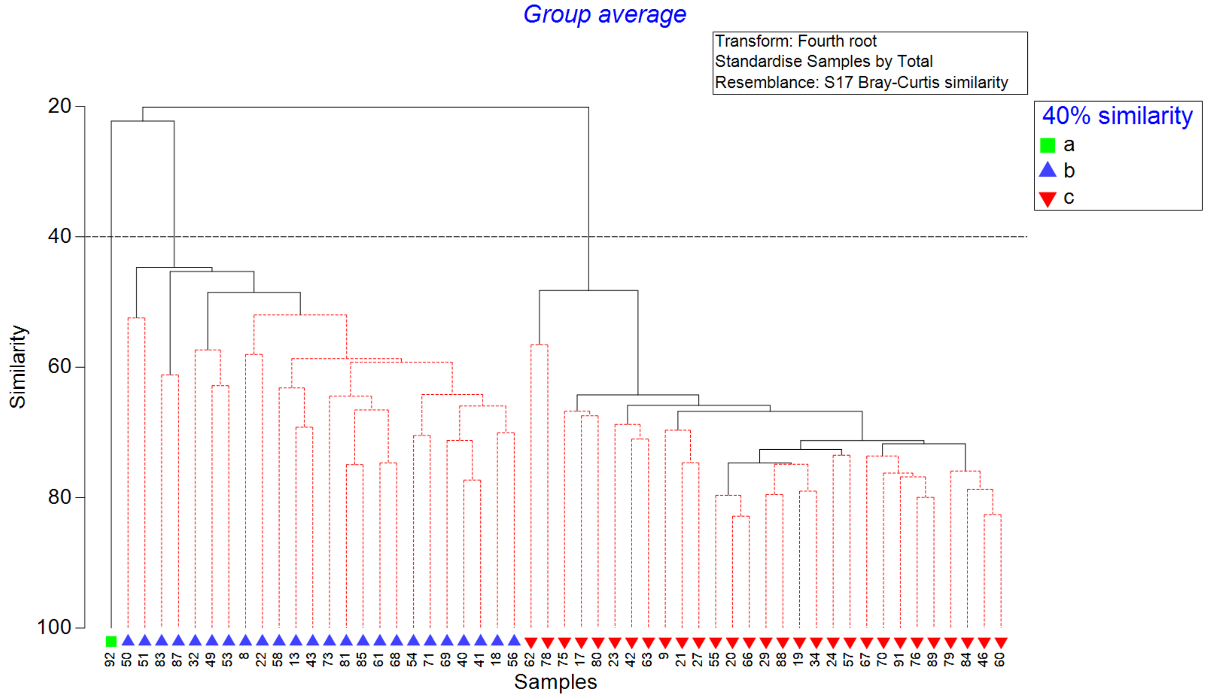

Figure 4. Dendrogram showing the results of hierarchical agglomerative clustering of Pobie Bank Reef epifauna sliced at 40% similarity (black dotted line) resulting in three cluster groups (a - c).

2.4. Habitats and Biotopes

Habitats and biotopes were identified and recorded from video transects by Seastar Survey Ltd. Marine Habitat Classification of Britain and Ireland (MHCBI v15.03) habitats and biotopes were determined to the highest possible complexity level, depending on the quality of the imagery. This ranged from biotope complex (level 4), biotope (level 5) to sub-biotope (level 6). If a video segment contained more than one clear biotope, the second was assigned as a secondary 'mosaic' biotope and recorded on a separate label tree in BIIGLE.

The habitat and biotope point map was designed to display as much detail as possible, including intra-station variation, and include mosaic habitats. To achieve this, the amount of time assigned to each biotope is displayed as a proportion of the total transect video duration at each station. This was calculated using R package 'lubridate' v1.9.3 (Grolemund & Wickham 2011) and mapped in QGIS v3.34 (QGIS Development Team 2023).

2.5. Priority Marine Features (PMFs)

Priority Marine Features were assigned from video segments in the same way as above by Seastar Survey Ltd. PMFs were determined using the descriptions and thresholds set out in (Tyler-Walters *et al.* 2016). Fish species were recorded as presence only, to prevent double counting.

2.6. Non-indigenous species (NIS)

All epifaunal taxa were identified from imagery to the highest attainable taxonomic resolution as described in section 2.2.5.1. These taxa were compared against lists of non-indigenous target species which have been selected for assessment of Good Environmental Status in UK waters under Marine Strategy Framework Directive (MSFD) Descriptor 2 and identified as significant by the GB Non-Native Species Secretariat (Eno, Clark & Sanderson 1997; Stebbing *et al.* 2014). These taxa are listed in Appendix 4.

2.7. Anthropogenic impact

Evidence of anthropogenic impact or marine litter was identified during imagery analysis by Seastar Survey Ltd. Observed pieces of litter or evidence of anthropogenic activity were tagged in BIIGLE using point annotations on a pre-designed label tree, using categories from the European Commission and listed in Appendix 5 (European Commission 2013).

Investigation of ICES abrasion layers (ICES 2021) show little to no demersal fishing occurring within the site between 2009 and 2016, likely due to the risk of fishing around the reef.

3. Results

3.1. Extent and distribution of Annex I reef

To address report Objective 1, the extent and distribution of Annex I reef has been determined using imagery, following the guidance by Irving (2009) for the designation of stony reef, as described in section 2.3.1. A habitat map incorporating bathymetric data will be published separately later.

Figure 5 shows the distribution of reef sub-types at stations across Pobie Bank Reef (stony reef, bedrock, a mixture of bedrock and stony reef, and no reef present). Reef sub-types were designated if present at one or more segments within the station transect, following checks of Irving (2009) stony reef criteria for reef composition outlined in Section 2.3.1. Out of the total 84 stations surveyed across PBR, 10 contained Annex I stony reef, 29 contained a mixture of stony reef and bedrock and eight contained bedrock only.

Table 6. Reef subtypes identified at PBR and number of stations in which each subtype is present (n = 84).

Reef subtype	n
Annex I stony reef	10
Annex I stony reef x bedrock	29
Bedrock	8
Not reef	37

A more detailed map is visible in Figure 6, which displays the relative duration of each reef sub-type within each transect as a proxy for the coverage of each reef sub-type per station. The maps show the patchiness of both rocky and stony reef both at individual stations and across the MPA as whole.

Station M001, in the south-west of the site, was designated as a test station and was excluded from reef and biotope analyses; consequently, it is not represented in Figures 5 or 6. Every other station visited during 1220S had video recorded, analysed and assessed for reef and biotope composition. The results are presented in the figures below.

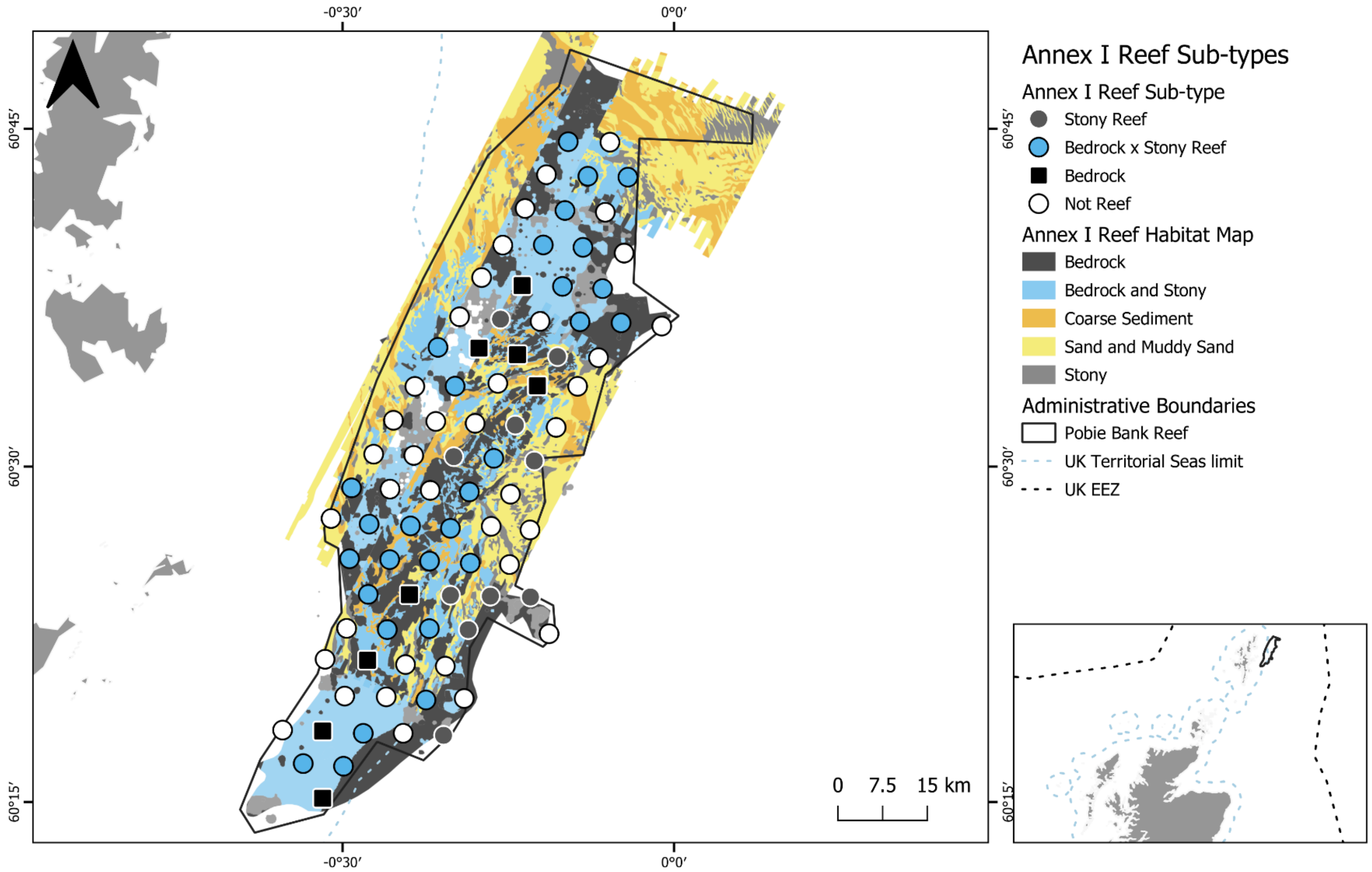

Figure 5. Annex I reef sub-types present at stations visited in 2020. Annex I reef habitat layers sourced from 1013S survey (2013) and Habitats Directive Annex I Reef data (2022). Stony reef characterising features examined are composition, elevation, extent and biota (Irving 2009).

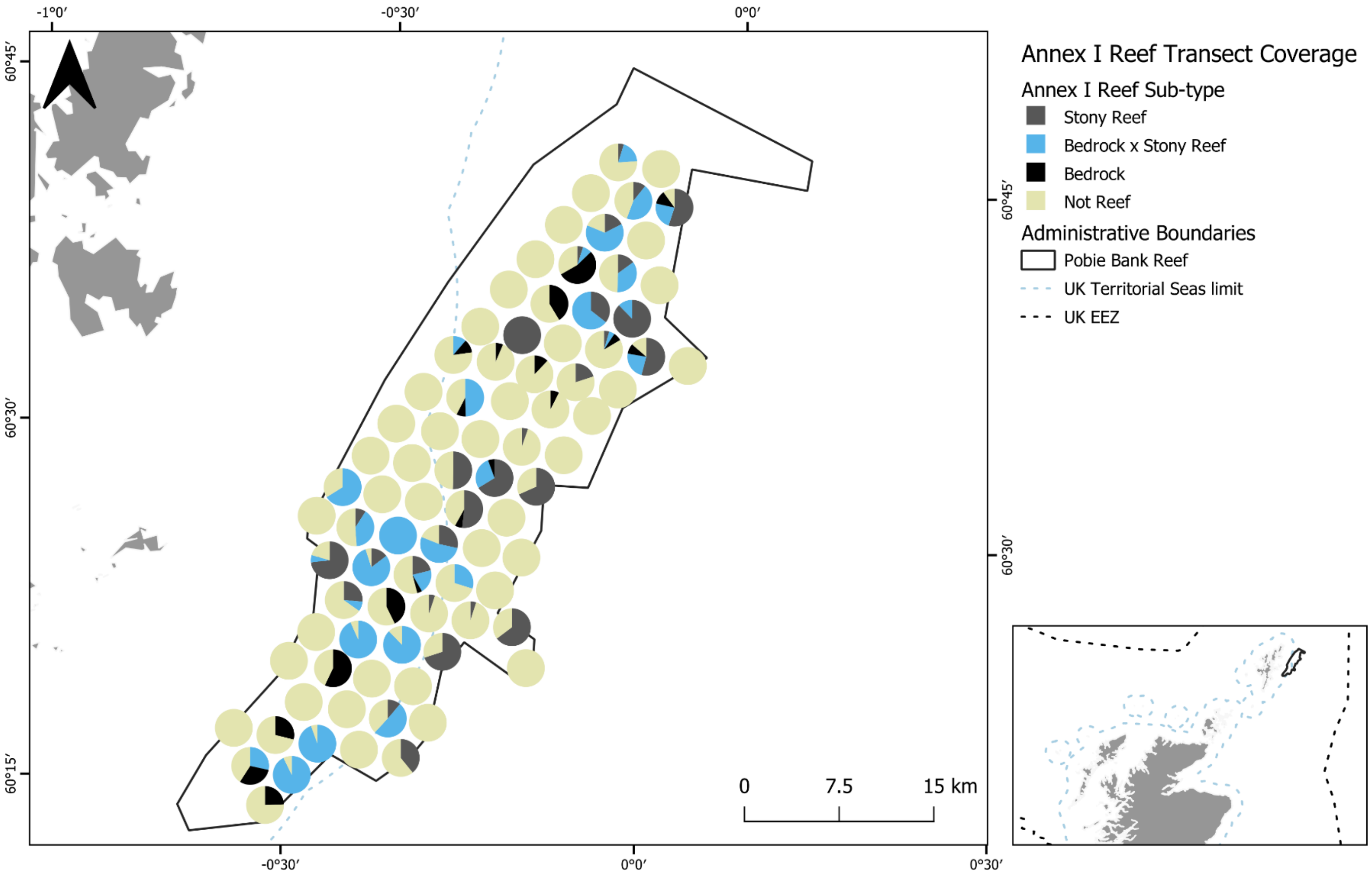

Figure 6. Annex I reef sub-types at stations visited in 2020, shown as a proportion of total transect video duration in seconds.

3.2. Epifaunal analysis

To address report Objective 2 (Table 2), univariate and multivariate analyses were undertaken in both habitats present at Pobie Bank Reef.

After truncation and pooling, there were 141 taxonomic units recorded within PBR, comprising of a mixture of species, genus, families and CATAMI morphological classifications (Althaus *et al.* 2015).

Due to limitations during the survey, only 54 out of 83 stations had sufficient imagery to achieve 70% sample coverage (see Section 2.3.2.3 for details). These stations were analysed using univariate and multivariate methods and the results are described below.

3.2.1. Univariate analysis

Univariate indices were calculated for each sample unit station. Sampling effort was standardised by using the same number of images from each station, making the stations comparable (see Section 2.3.2.3). The indices can be used to inform an ecological baseline of epifaunal communities across PBR. Mean values are shown along with standard error for the analysed stations across the site (Table 7). These values may be compared with data collected in future to assess change in ecological communities.

Table 7. Univariate indices of diversity per station across Pobie Bank Reef MPA (n = 54).

Univariate index	Mean	Standard Error
Species richness (S)	34.09	2.81
Abundance (N)	1015.43	185.76
Pielou's evenness (J')	0.49	0.03
Shannon's diversity index (H')	1.55	0.07

Variation in univariate measures species richness, abundance, Pielou's evenness and Shannon's diversity index are illustrated in Figure 7. The figure shows that the stations with the highest numbers of taxa are not correlated with those which have the highest diversity. Combined with Pielou's Evenness, this indicates that these stations are dominated by few taxa. Cross-referencing these values with reef designation indicates that high diversity stations are designated as stony reef, however not all stations with designated reef have high taxonomic diversity.

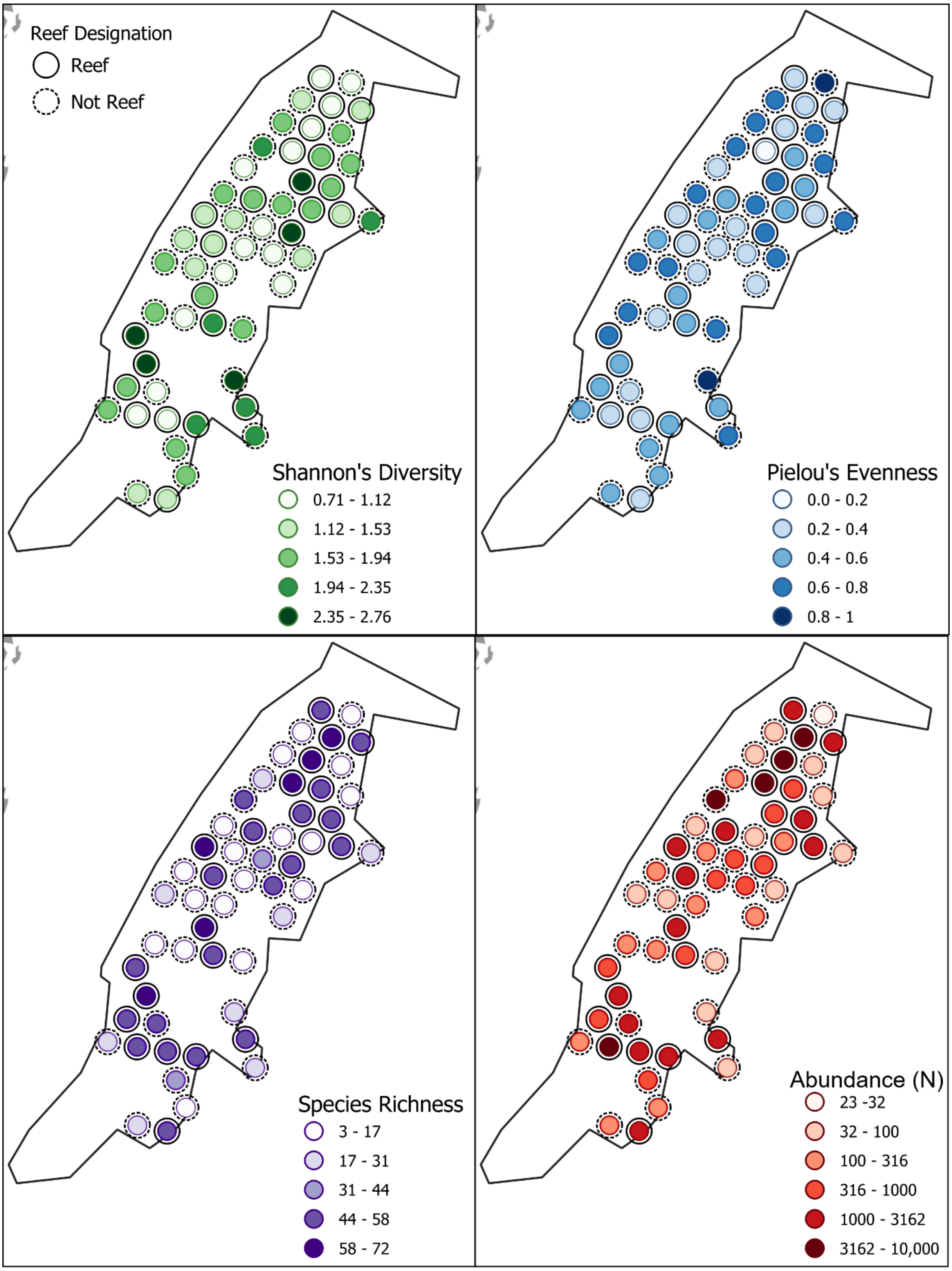

Figure 7. Map of PBR showing variation in univariate indices (Shannon's diversity, Pielou's evenness, species richness and abundance) and stations where Annex I stony reef was found. Data illustrated is from 1220S only. Only stations with ≥ 14 images are comparable and plotted.

3.2.2. Multivariate analysis

3.2.2.1. Characteristic communities

Fourteen statistically distinct epifaunal clusters (a - n) were identified using SIMPROF and were grouped into three main assemblages at 40% similarity (Figure 8a). A BVSTEP analysis was run to find the smallest subset of epifauna whose variation best matches that of the overall assemblage. The taxa identified can be interpreted as a group of indicator species. This was found to be Serpulidae / Tube Worms, orange encrusting bryozoa, *Adamsia palliata* (Cloak Anemone), *Caryophyllia smithii* (Devonshire Cup Coral) and *Ophiura albida* (Serpent's Table Brittlestar) and is shown overlaid onto the epifaunal nMDS plot in Figure 8c. The vectors show that the presence of *C. smithii* and the encrusting orange Bryozoan (Fig. 8c) are associated with data points which are also associated with the presence of cobbles (Fig. 8b). On the other hand, data points associated with Tube Worms / Serpulids and *A. palliata* are positively associated with coverage of sand and granules.

The taxa identified as characteristic epifauna for each cluster are outlined in Table 8 below and displayed geographically in Figure 9. Due to high levels of similarity between each of the many SIMPROF clusters, differences in fauna have been analysed for the three groups resulting from 40% similarity. Group A contained only one station, subsequently no similarity scores can be calculated. Using a combination of similarity and dissimilarity values derived from SIMPER analysis, the fauna associated with each cluster group can be distinguished. Group A contained only two taxa within the whole station, which were *Spatangus purpureus* (Purple Heart Urchin) and *Lanice conchilega* (Sand Mason Worm). Group B contained fewer taxa at lower abundances than Group C, but more than A. Taxa present at higher abundances than both other groups included Tube Worms, *L. conchilega*, and *S. purpureus*. Group C contained taxa associated with hard substrates including higher abundances of *C. smithii* (Devonshire Cup Coral), the bryozoan *Omalosecosa ramulosa*, Brachiopoda, Galatheidae (Squat Lobster family), the brittlestar *Ophiothrix fragilis*, Caridea (Caridean Shrimp) and barnacles.

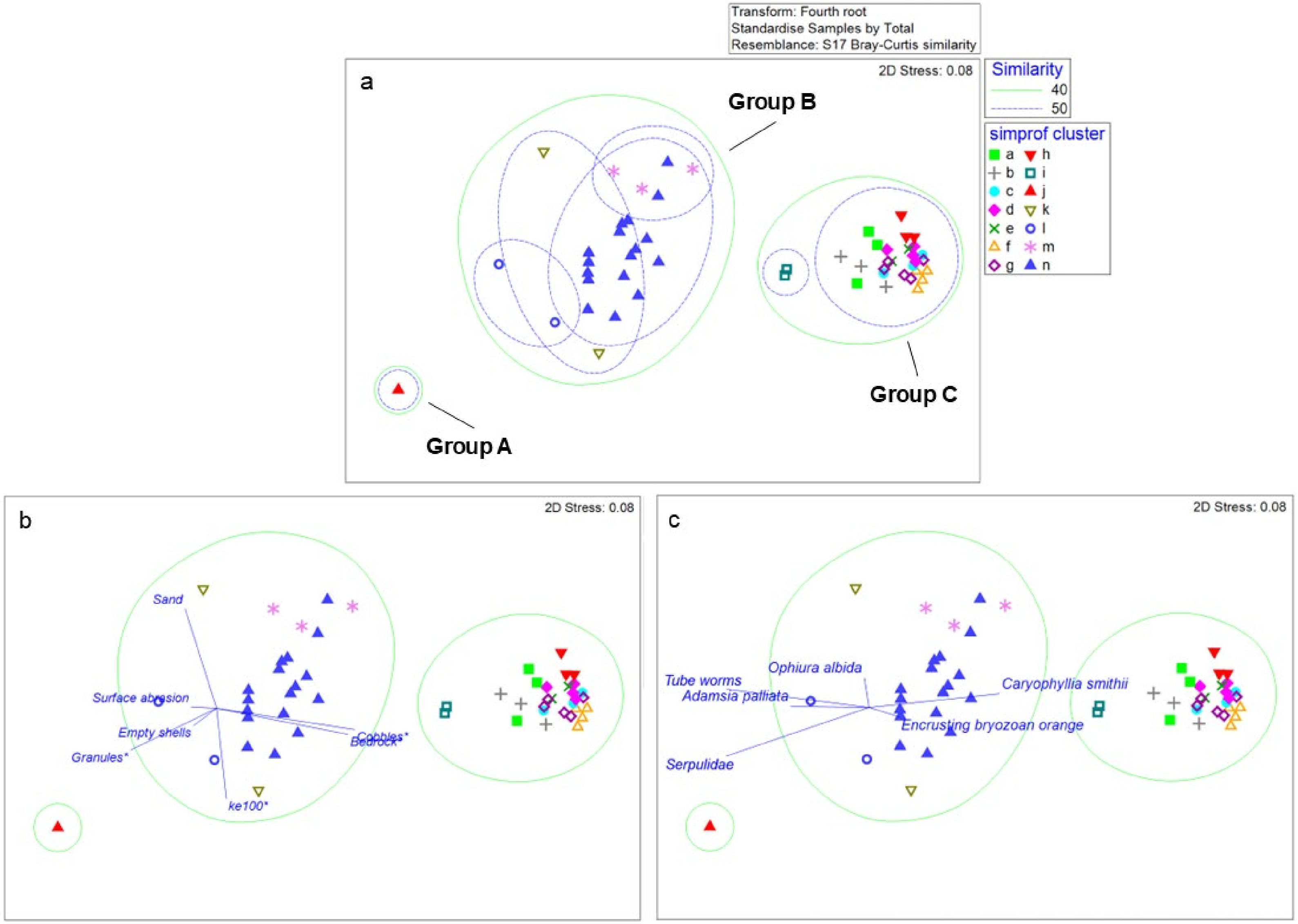

Figure 8a. nMDS plot showing ordination of standardised epifaunal data per station. SIMPROF clusters displayed as symbols. Ellipses indicating 40% (green) and 50% (blue dashed) intra-group similarity are superimposed. 40% cluster groups labelled A, B and C from left to right.

Figure 8b. Vectors display strength and direction of most influential environmental explanatory variables on epifaunal assemblages at PBR. 'ke100' represents peak current energy on the seabed. Variables with an asterisk (*) were selected in final model (best, BIC).

Figure 8c. Vectors display results of BVSTEP analysis, strength and direction of vectors indicate most influential taxa driving variation in between clusters.

Table 8. SIMPER analysis results for the top five characterising taxa in cluster groups A – C identified from epifaunal clustering at 40% similarity across Pobie Bank Reef.

Group	Average Similarity	Top 5 Taxa	Average Abundance	% Contribution	Similarity/SD
A	< 2 samples in group				
B	54.95	Tube Worms	1.14	21.18	3.59
		Serpulidae	0.75	14.58	6.72
		Ophiuroidea	1.01	12.80	1.42
		Lanice conchilega	0.72	10.75	1.53
		Paguridae	0.62	10.71	2.84
C	65.31	*Caryophyllia smithii*	2.70	8.32	3.17
		Omalosecosa ramulosa	1.49	5.19	5.20
		Ophiuroidea	1.42	4.84	2.74
		Brachiopoda	1.21	3.88	3.06
		Faunal crust indet.	1.03	3.61	6.77

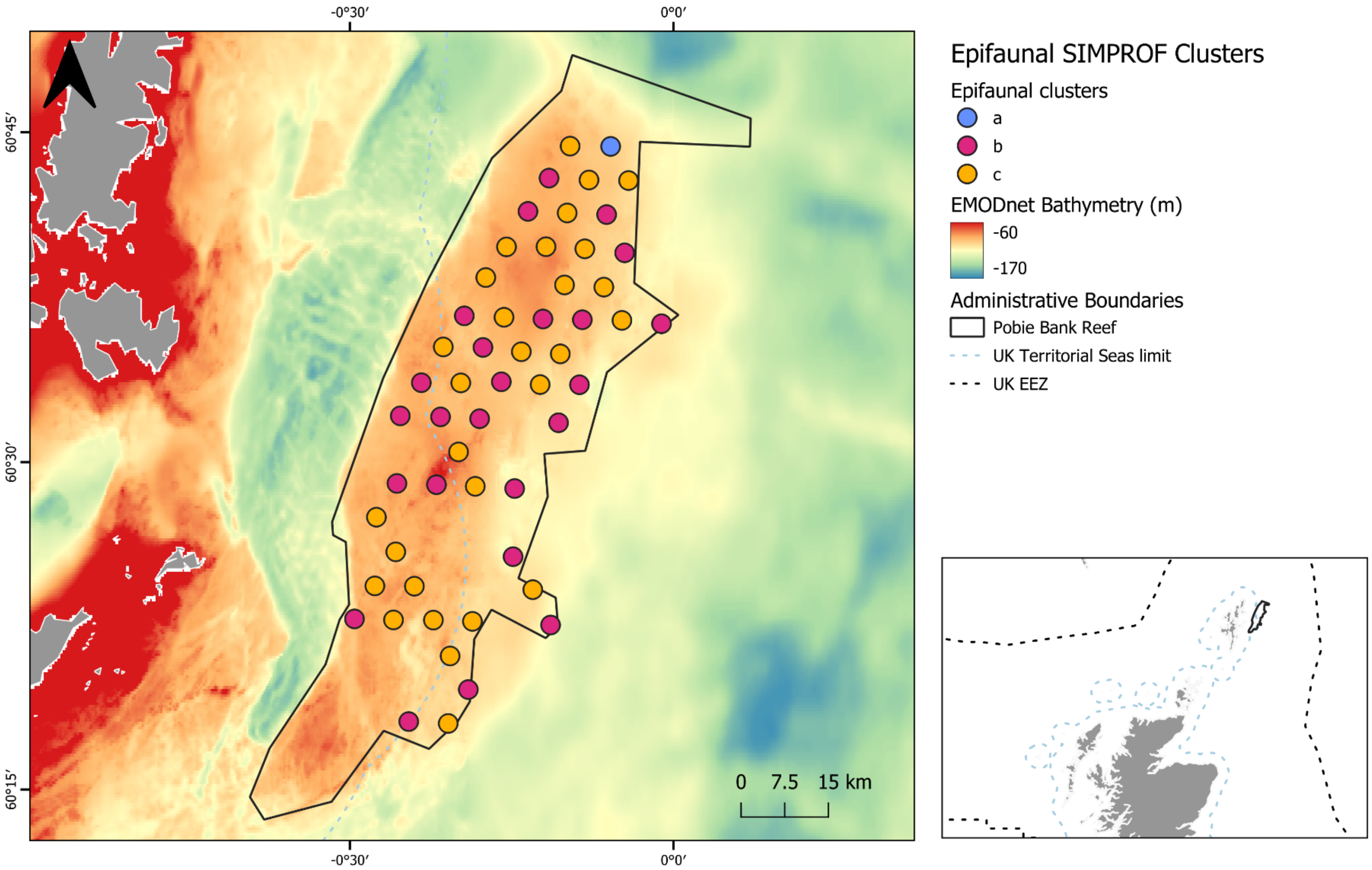

Figure 9. Epifauna clustered at 40% similarity at Pobie Bank Reef MPA overlaid on bathymetry from EMODnet (2015)

3.2.2.2. Supporting processes

Environmental drivers, including depth, seabed abrasion, kinetic energy at the seabed, and sediment cover were analysed to investigate their influence on epifaunal communities. It should be noted that as the survey was imagery-only, sediment composition was estimated visually as percentage cover rather than by Particle Size Analysis (PSA), which requires grab data. Correlations among predictors were examined using a Draftsman's plot, where no correlations exceeded 0.90 and therefore all variables were retained.

A distance-based linear model (DistLM) was applied to 14 environmental predictors to investigate drivers of variation in assemblage structure. Model selection was undertaken using three complementary approaches: Best with AIC, best with BIC, and forward selection by R^2. Across all methods, substrate composition was identified as a dominant driver of variation, particularly the coverage of bedrock and cobbles, which entered first in the forward selection process and were both retained in all top-ranked models. Granules were also strongly associated with epifaunal variation and were consistently selected into the 'best' model, regardless of the selection criterion used. Peak kinetic energy from currents acting on the seabed (ke100) was identified as a secondary but robust contributor, appearing in the most parsimonious BIC model and showing significant improvement in the forward run model.

The BIC criterion, which imposes the strongest penalty for complexity, selected a four-variable model comprising bedrock, cobbles, current energy, and granules, explaining 59.1% of variation (BIC = 383.29) (Table 9). The results appeared to indicate some redundancy in choice between granules and empty shells, and wave energy or current energy; as switching the chosen variable resulted in similar BIC and R^2 values. In contrast, the AIC-based best selection procedure favoured a larger seven-variable model (additionally including surface abrasion, empty shells and sand), increasing the proportion of variation explained to 64.7% (AIC = 371.49) but incorporating some non-significant terms that improved AIC (surface abrasion p = 0.275, empty shells p = 0.094). Forward selection by R^2 ultimately included all 13 predictors, but additions to the model after the selection of cobbles, bedrock, current energy, granules and sand contributed negligible gains and lacked statistical support (e.g. depth p = 0.143).

The final model was selected by prioritising parsimony and conditional significance, resulting in the retention of cobbles, bedrock, granules and current energy as the key environmental drivers of observed variation in the epifaunal assemblage. Pseudo-F values indicate the strength of the relationship between that variable and the multivariate assemblage structure relative to residual variation. Higher pseudo-F values, combined with low p-values, reflect strong evidence of association (e.g. cobbles pseudo-F = 37.37, p = 0.001), whereas lower pseudo-F values indicate weaker relationships. While additional variables such as empty shells and sand may influence assemblage composition, their effects appear to be secondary and less consistent across selection criteria. This was backed-up by the results of the Bio-Env analysis, which identified bedrock, cobbles and sand as the three most influential variables on the epifaunal assemblage.

Table 9. Marginal test results of DistLM analysis of investigated explanatory environmental variables. Variables with an asterisk (*) were selected into the most parsimonious model, as decided by 'Best' selection procedure using BIC criterion ($R^2 = 0.59$). SS = sum of squares, Proportion = proportion of variation explained.

Explanatory environmental variable	SS (trace)	Pseudo-F	P	Proportion (%)
Cobbles*	46,187	37.368	0.001	41.81
Bedrock*	41599	31.413	0.001	37.66
Small boulders	33,234	22.378	0.001	30.09
Biogenic rubble	23,215	13.837	0.001	21.02
Granules*	17,018	9.4705	0.001	15.41
Depth	8054.4	4.0899	0.018	7.29
Sand	6875.3	3.4514	0.027	6.22
Medium boulders	6647.4	3.3297	0.018	6.02
Empty shells	4363.1	2.1384	0.074	3.95
Peak seabed kinetic energy due to waves (ke100w)	3948.8	1.9278	0.105	3.57
Peak seabed kinetic energy due to currents (ke100)*	3256.2	1.5795	0.155	2.94
Total surface abrasion (swept area ratio 2016–20)	2317.8	1.1145	0.281	2.09
Large boulders	1943.8	0.93146	0.428	1.76
Total sub-surface abrasion (swept area ratio 2016–20)	973.8	0.4625	0.764	0.88

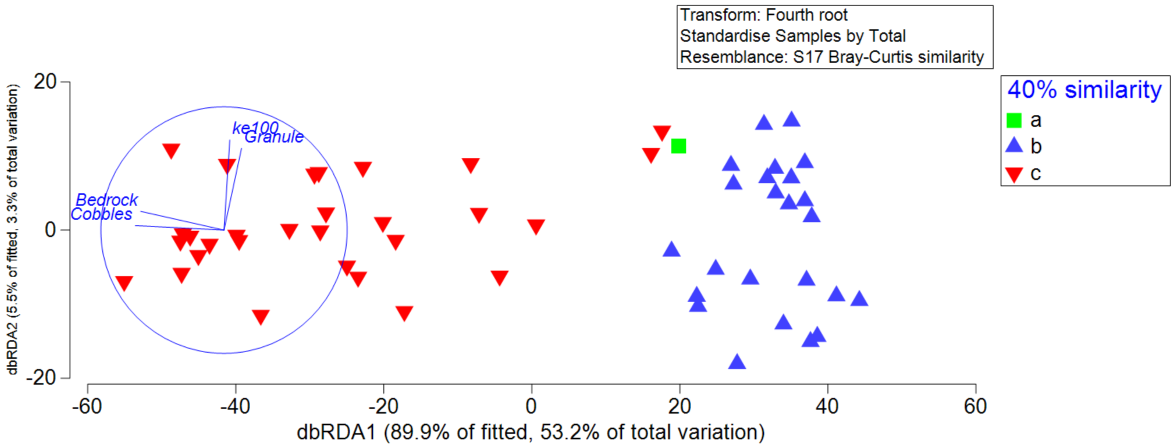

Figure 10. dbRDA of the BIC best selected model (cobbles, biogenic rubble, ke100w).

The distance-based redundancy analysis (dbRDA) is an ordination of fitted values from the multivariate regression model, representing the relationship between predictor variables and the multivariate data. Figure 10 shows that the first axis, dbRDA1, explains 89.9% of the fitted model, which is 53.2% of the total variation in of the epifaunal assemblage. The second axis, dbRDA2 explains only 5.5% of the fitted model in comparison, 3.3% of the total epifaunal variation. The vectors overlaid on the diagram indicate that the coverage of cobbles and bedrock can account for much of the differentiation of the clusters across the dbRDA1 axis, but that the proportion of granules and kinetic energy from currents causes variation in the dbRDA2 axis, causing much of the variation in group b.

3.3. Habitats and Biotopes

The closest matches of MHCBI habitats and biotopes to faunal groupings are described below. Seven biotopes were identified at PBR, of which one represents coarse substrate, and the remaining six represent biotopes based on moderate or high energy rock. Table 10 below additionally lists seven biotope combinations which were found to occur within segments.

Table 10. Habitats and biotopes identified at PBR and number of stations in which each biotope is present.

Habitat/Biotope	MHCBI Classification	n
SS.SCS.OCS	Offshore circalittoral coarse sediment	76
CR.HCR.DpSp.PhaAxi	*Phakellia ventilabrum* and Axinellid sponges on deep, wave-exposed circalittoral rock	43
CR.MCR.EcCr.FaAlCr	Faunal and algal crusts on exposed to moderately wave-exposed circalittoral rock	14
CR.MCR.EcCr	Echinoderms and crustose communities	13
SS.SCS.OCS x CR.HCR.DpSp.PhaAxi	-	8
CR.MCR.EcCr.CarSp	*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock	7
CR.MCR.EcCr.CarSp.Bri	Brittlestars overlying coralline crusts, *Parasmittina trispinosa* and *Caryophyllia smithii* on wave-exposed circalittoral rock	5
CR.HCR.DpSp.PhaAxi x SS.SCS.OCS	-	4
SS.SCS.OCS x CR.MCR.EcCr	-	3
CR.MCR.EcCr.CarSp x SS.SCS.OCS	-	1
CR.MCR.EcCr.FaAlCr x SS.SCS.OCS	-	1
CR.MCR.EcCr.FaAlCr.Bri	Brittlestars on faunal and algal encrusted exposed to moderately wave-exposed circalittoral rock	1
SS.SCS.OCS x CR.MCR	-	1
SS.SCS.OCS x CR.MCR.EcCr.FaAlCr.Car	-	1

Figure 11 shows the geographic distribution of habitats and biotopes identified from video transects, with proportions based on total duration of habitats and biotopes per station. Secondary mosaic habitats are represented in the figure as separate categories, combined with a primary biotope (e.g. SS.SCS.OCS x CR.MCR - offshore circalittoral coarse sediment with secondary moderate energy circalittoral rock habitat).

Two video segments were identified as being Annex I bedrock reef, while the biotope was identified solely as offshore circalittoral coarse sediment. Although a corresponding rock biotope might be expected, a veneer of coarse sediment is evident in the imagery, limiting the visible extent of the bedrock and its associated epifauna. The occurrence of epifauna only on areas of exposed bedrock supports the Annex I bedrock reef classification, though the limited extent of visible bedrock in the video segments meant that assignment of a rock biotope was not supported.

Another feature of note from the imagery is the presence of biogenic rubble in the form of broken erect bryozoa and cup corals, which were often observed on the coarse substrate adjacent to patches of reef.

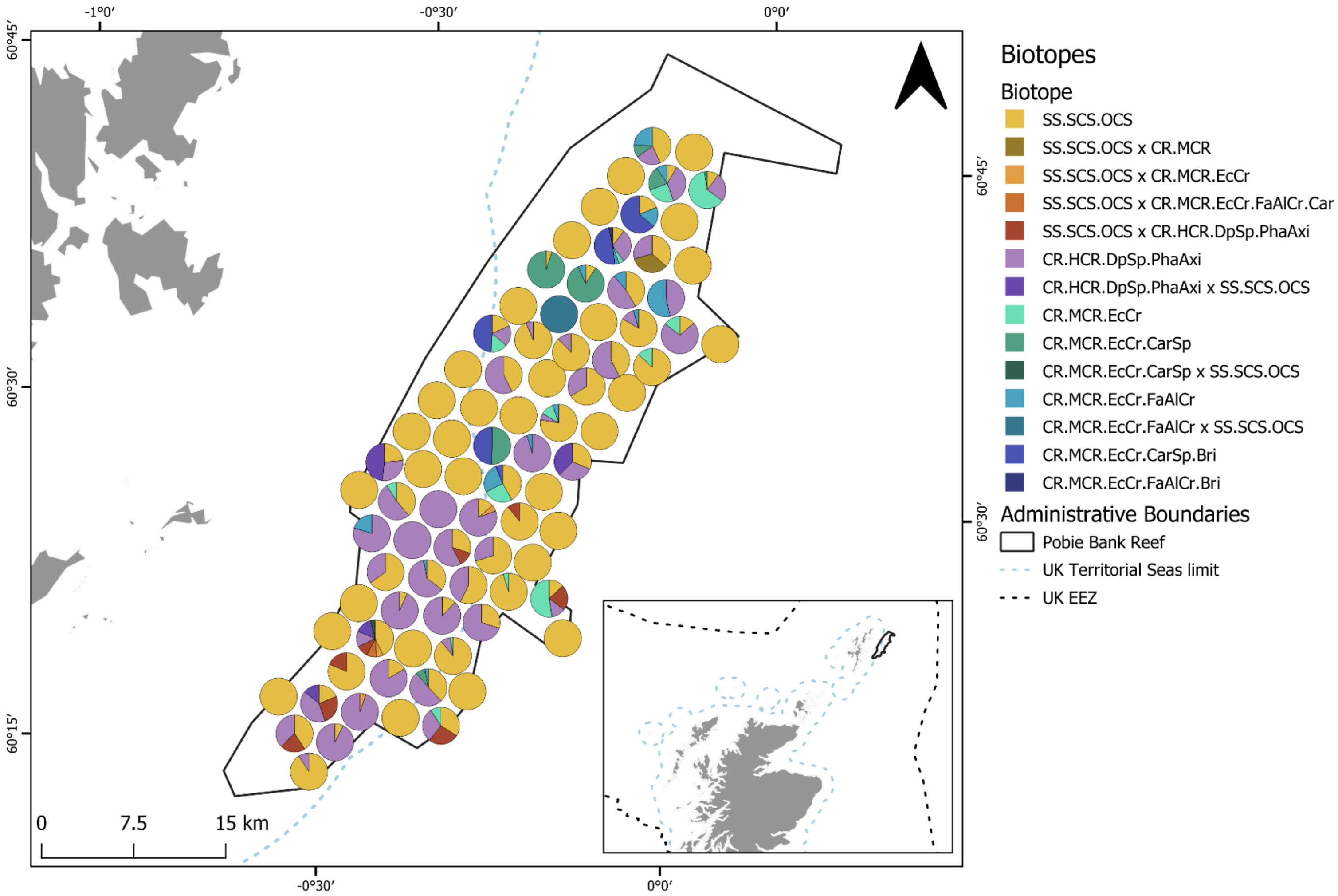

Figure 11. Habitats and biotopes at each survey station visited, portrayed as a proportion of total transect video duration. Combinations of biotopes represent the primary and secondary biotopes within a video segment.

3.4. Priority Marine Features (PMFs)

The Priority Marine Feature (PMF) habitats assigned to Pobie Bank Reef were 'Offshore subtidal sands and gravels' and 'Deep sponge communities (circalittoral)', part of the 'Northern Sea fan and sponge communities' PMF habitat.

PMF species identified include *Arachnanthus sarsi*, *Lophius piscatorius* (Monkfish), *Molva molva* (Ling), Ammodytidae (Sandeel, not possible to identify genus or species), *Trisopterus* sp. (Striped Gadoid, not possible to identify species), and possible *Trisopterus esmarkii* (Norway Pout). A complete list of PMF species identified can be found in Table 11 below.

Table 11. PMF species observed in stills and video collected from drop-camera tows at PBR.

Taxonomic name	Common name
Molva molva	Ling (European Ling)
Lophius piscatorius	Anglerfish (Monkfish, White-Bellied Monkfish, Sea Monkfish)
Arachnanthus sarsi	Burrowing Sea Anemone (Scarce Tube-Dwelling Anemone)
Pollachius virens	Saithe (Coalfish, Coaly, Coley, Billet, Green Code, Glassan, Glosshan, Sillock)
Leucoraja naevus	Sandy Ray (Sandy Skate, Leather Ray, Faroese Roker)
Ammodytidae	Sandeel (Raitt's Sandeel, Lesser Sandeel, Small Sandeel)
Trisopterus esmarkii	Norway Pout

3.5. Non-indigenous species (NIS)

No non-indigenous species listed in the NIS list were observed at Pobie Bank Reef MPA (Stebbing *et al.* 2014).

3.6. Anthropogenic impact

3.6.1. Anthropogenic activities

Biogenic rubble was prevalent in the site, with damage to erect species including *Omalosecosa ramulosa* and cup sponges. This is demonstrated in one image at station M084 which shows broken-off *O. ramulosa* colonies entangled in fishing line, a potential indication of damage attributable to fishing activities.

3.6.2. Marine litter

Non-natural materials were observed in eight camera tow transects at Pobie Bank Reef MPA (Table 12; Figure 12). Further detail on the litter categories can be found in Appendix 5.

Table 12. Marine litter observed in video collected from drop-camera tows.

Station Code	Date	Marine Litter Category
M012	24/08/2020	F - Miscellaneous
M013	24/08/2020	D2 - Bottle
M031	25/08/2020	F - Miscellaneous
M057	31/08/2020	A14 - Other
M067	26/08/2020	B8 - Other
M080	01/09/2020	F - Miscellaneous
M081	26/08/2020	F - Miscellaneous
M084	01/09/2020	A6 - Fishing Line (Entangled)

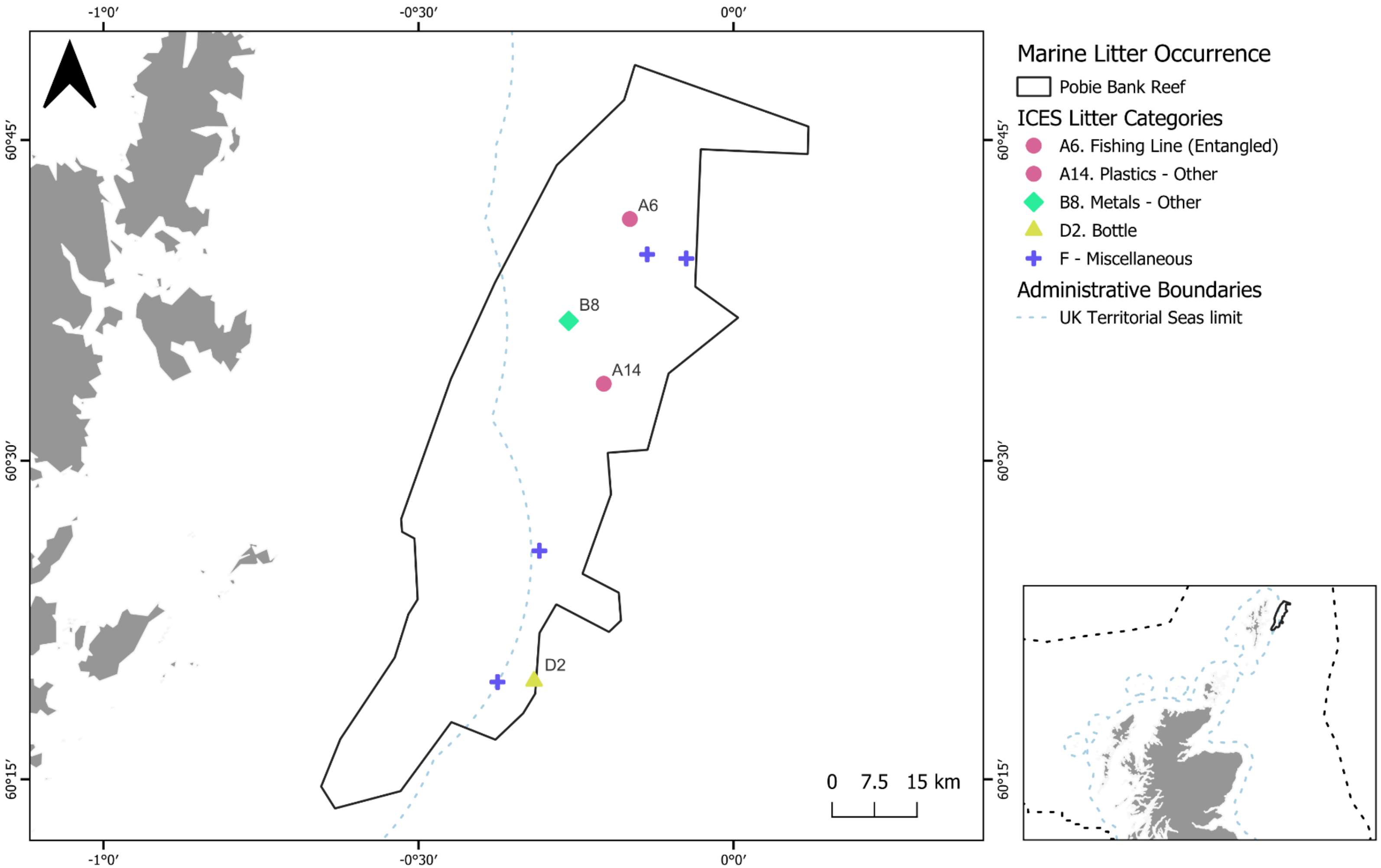

Figure 12. Locations of marine litter identified in video transects on the 1220S survey to Pobie Bank Reef MPA.

4. Discussion

4.1. Extent and distribution of Annex I reef

Annex I reef was found at approximately half of all stations visited in 2020. Bedrock and stony reef are widely distributed throughout the site, with 39 of 84 visited stations meeting the criteria set out by Irving (2009) for stony reef, and 8 stations containing only bedrock.

While Figure 5 provides an indication of the presence of Annex I reef throughout the site, maps of Annex I reef showing the extent and distribution of the habitats should rely on a combination of both point and polygon data (Duncan *et al.* 2022). Here, point data has been generated from video and still images collected from relatively short transects with a limited field of view. These data provide a snapshot of the environment from a relatively small area at each station. Annex I reef polygon data at Pobie Bank Reef is generated from the interpretation of both multibeam and sidescan acoustic datasets, which cover a much greater spatial extent. Due to the inherent patchiness of both rocky and stony reef at the site, it's important to consider both the finer scale point generated from imagery data and the more comprehensive polygon data from acoustic data when determining the extent and distribution of Annex I reef in the site.

4.2. Characteristic biological communities

Biological communities were assessed for 54 stations which were deemed to have a statistically robust sample size of imagery available, which is 65% of the stations visited during this survey.

Epifaunal communities at the site appear strongly associated with their habitat as the assemblages were broadly split between hard substrate and coarse sediment epifauna. The most common habitats and biotopes present were 'offshore circalittoral coarse sediment', followed by '*Phakellia ventilabrum* and Axinellid sponges on deep, wave-exposed circalittoral rock'. Biotope classification in both habitats is likely to rely on infaunal data, however due to the patchiness of reef features and the shallow depth of the sediment over rock, this is difficult to achieve in rocky habitats. Taxa associated with the hard substrate (indicated by proportion of cobbles and granules) were *C. caryophyllia* (Devonshire Cup Corals), *O. ramulosa* (Bryozoan) and Brachiopoda. Other taxa associated with this habitat were Galatheidae (Squat Lobster family), *O. fragilis* (Brittlestar species), Caridea (Caridean Shrimp) and barnacles.

Coarse sediments were associated with taxa such as Serpulidae Tube Worms, *L. conchilega* (Sand Mason Worm) and Paguridae crabs. *A. palliata* (Cloak Anemone) and *O. albida* (Serpent's Table Brittlestar) were also found to explain a high proportion of variation in epifaunal assemblages due to their strong association with coarse sediment. Ophiuroidea brittlestars were found across hard and softer substrates.

The mapping of univariate indices in Figure 7 illustrates high variability in diversity and abundance from station to station. This appears to be closely linked to the presence of reef at a station, as reef stations appear to have the highest levels of species richness. Low levels of Pielou's Evenness at stations where there are high raw abundances (N) indicate dominance of the assemblage by one or two taxa. At hard substrate stations this is likely to be *C. caryophyllia*.

The strongest environmental influences on the epifaunal assemblage were the substrate composition, particularly coverage of bedrock and cobbles, with hydrodynamic exposure exerting a secondary influence. This is consistent with representation of the epifaunal assemblages in the cluster diagram (Figure 8) which demonstrates a clear separation between ‘rocky reef’ and coarse sediment communities. The findings are consistent with existing knowledge about Pobie Bank Reef, with biological assemblages highly dependent on the designated bedrock and stony reef features. The inclusion of peak wave-driven kinetic energy in the selected model reflects the importance of hydrodynamics on epifaunal assemblages, which can influence scour, sediment mobility and nutrient availability.

The most highly fitted model option (containing all measured environmental variables) explained approximately 70% of variation in the epifaunal assemblage, suggesting the influence of other, unmeasured environmental factors, such as proximity of coarse sediment communities to rocky reef (Barros, Underwood & Lindegarth 2001), fine-scale habitat heterogeneity, rugosity and complexity (Sola & Griffin 2025) or biological variables such as dispersal and competition.

4.3. Limitations

The primary limitation of this report was the insufficient volume of imagery available to support a robust, site-wide analysis of epifaunal assemblages. Due to operational constraints (such as COVID restrictions at the time of the survey) and limited survey time, transects were restricted to 10 minutes in duration. At the time of the survey, power analysis methods indicated that this would be adequate for data collection, however, current best practice for image-based analysis requires the definition of sample units through an imagery pooling approach (as outlined in Section 2.3.2.3), which does not treat individual images as independent samples, and therefore required a larger volume of imagery than predicted. Although the imagery collected per station was insufficient to achieve the recommended 90% sampling coverage, reducing the target to 70% enabled 54 stations to meet the minimum data threshold.

The 2023 survey at Pobie Bank Reef collected a substantially greater volume of imagery than in 2020 (Tangye & Stirling 2024), which is likely to be sufficient to support robust epifaunal analyses and address the limitations of previous surveys. However, it remains essential to maintain this standard in future monitoring efforts both at PBR and across other MPAs by applying the below recommendations.

5. Recommendations

5.1. Operational and survey strategy

- Clearly defined research questions and respective hypotheses should be established during the survey planning phase to guide spatial and methodological design, ensuring that data collection is aligned with analytical objectives (Clewett *et al.* 2024).

- Future surveys should use data from previous visits to Pobie Bank Reef MPA, including in 2020, to calculate the required sample unit size of still imagery. A larger data pool will increase the accuracy and confidence of the estimated sample size required for future surveys. This could be further refined based on the predominant habitat at each station, as stations which have a higher reef coverage will not require as many images as those with higher coarse substrate coverage.

- To ensure adequate imagery for analysis following quality assurance procedures, monitoring survey plans should aim for the number of images collected to exceed the target sample unit size by a minimum of 50%. Additionally, during the survey itself, image quality should be continuously monitored during collection to ensure that sufficient imagery is collected, particularly regarding the effects of weather conditions, turbidity and sediment type. These factors can strongly impact image clarity and suitability for analysis.

- Stations to the north and west of the site should be included in subsequent surveys as they were not visited in 2020. This is particularly pertinent as some of these stations are situated in areas which are excluded from management measures brought into force in 2025 (Scottish Government 2025).

5.2. Analysis and interpretation

5.2.1. Imagery annotation

- Contractors conducting imagery analysis should ensure each taxon is enumerated using the same method throughout the analysis (i.e. either count or percentage cover). If any changes are made to the chosen method for a particular taxon, previously completed images should be re-analysed and the removal of the former data type from the data frame should be ensured. Where possible the enumeration type chosen should also be consistent throughout a taxonomic group.

- It may be beneficial for the wider group of MPA stakeholders to have access to a folder of characterising images for the site. This collection could support communications efforts by showcasing key or notable taxa, habitats and evidence of anthropogenic activity. The contractor could efficiently compile this resource during the imagery annotation process.

5.2.2. Analysis and reporting

- Subsequent monitoring reports for Pobie Bank Reef within this time series are expected to obtain sufficient imagery to support epifaunal community analysis at all stations across the site. While this survey may serve as a baseline (T_0) for certain univariate metrics, enabling temporal comparisons such as change in diversity or evenness indices, multivariate analyses will be constrained by the absence of T_0 data from some stations in 2020. As a result, future multivariate assessments may be limited in spatial resolution or require methodological adjustments to account for incomplete baseline coverage.

- To further examine the influence of hydrodynamic conditions on epifaunal assemblage structure and to assess potential relationships with nutrient availability, the deployment of a CTD is recommended to determine mixed-layer depth. The acquisition of chlorophyll concentration and plankton abundance and diversity data could also be undertaken to provide insight into nutrient distribution across the site and its variability with depth.

6. References

Akaike, H. (1973) 'Maximum likelihood identification of Gaussian autoregressive moving average models', *Biometrika*, 60(2), pp. 255–265. https://doi.org/10.1093/biomet/60.2.255

Albrecht, J. & Stirling, D. (2021) Pobie Bank Reef Special Area of Conservation 2020 Cruise Report (1220S). *JNCC/MSS Partnership Report 5*. Peterborough: JNCC. https://data.jncc.gov.uk/data/f207f461-207e-417b-8d54-d91d9c04d52c

Allaby, M. (2015) *A dictionary of ecology* (5th edition). Oxford University Press, UK.

Althaus, F. *et al*. (2015) 'A Standardised Vocabulary for Identifying Benthic Biota and Substrata from Underwater Imagery: The CATAMI Classification Scheme', *PLOS ONE*. Edited by J. Hewitt, 10(10), p. e0141039. https://doi.org/10.1371/journal.pone.0141039

Anderson, M. (2024) 'Pers. Comm.'

Barros, F., Underwood, A.J. & Lindegarth, M. (2001) 'The Influence of Rocky Reefs on Structure of Benthic Macrofauna in Nearby Soft-sediments', *Estuarine, Coastal and Shelf Science*, 52(2), pp. 191–199. https://doi.org/10.1006/ecss.2000.0734

Brown, A.E., Burn, A.J., Hopkins, J.J. & Way, S.F. (1997) The Habitats Directive: selection of Special Areas of Conservation in the UK, *JNCC Report 270*. JNCC, Peterborough, ISSN 0963-80-91 https://jncc.gov.uk/resources/5d20b480-9cc1-490f-9599-da6003928434

Chao, A. & Jost, L. (2012) 'Coverage-based rarefaction and extrapolation: standardizing samples by completeness rather than size', *Ecology*, 93(12), pp. 2533–2547. https://doi.org/10.1890/11-1952.1

Church, N.J., Carter, A.J., Tobin, D., Edwards, D., Eassom, A., Cameron, A., Johnson, G.E., Robson, L.M. & Webb, K.E. (2016) JNCC Pressure Mapping Methodology. Physical Damage (Reversible Change) – Penetration and/or disturbance of the substrate below the surface of the seabed, including abrasion. *JNCC Report 515*. JNCC, Peterborough, ISSN 0963-8091 https://jncc.gov.uk/resources/5874e65d-324b-4f6b-bce2-bfc7aab5ba7f

Clarke, K.R. & Gorley, R.N. (2015) PRIMER v7: User Manual/Tutorial. Plymouth, p. 300.

Clewett, R., Close, H., Lozach, S., McBreen, F. & Albrecht, J. (2024) Image Processing and Statistical Analysis for MPA Monitoring (Workshop Report). *JNCC Report 770* (Workshop Report), JNCC, Peterborough, ISSN 0963-8091 https://hub.jncc.gov.uk/assets/1a9583d1-105c-4fe4-b17b-835a1a075c59 (Accessed: 15 November 2024).

Dudley, N. (2008) Guidelines for applying Protected Area management categories. IUCN, Gland.

Duncan, G. *et al.* (2022) Method for creating version 8 of the UK composite map of Annex I Reefs. JNCC Methods Report. Peterborough: Joint Nature Conservation Committee.

Eno, N.C., Clark, R.A. & Sanderson, W.G. (1997) Non-native marine species in British waters: a review and directory. Joint Nature Conservation Committee, Peterborough, UK.

European Commission (2013) Guidance on monitoring of marine litter in European Seas. MSFD Technical Subgroup on Marine Litter. JRC Scientific and Policy Reports. https://circabc.europa.eu/sd/a/d3d0aa0f-c4c2-4b82-afe8-79f9f4d23560/MSCG-11_2013_10c MSFD Guidance on Monitoring Marine Litter.pdf (Accessed: 27 April 2020).

European Commission (2015) The EU birds and habitats directives. European Union. https://data.europa.eu/doi/10.2779/49288 (Accessed: 15 November 2024).

Grolemund, G. & Wickham, H. (2011) 'Dates and Times Made Easy with lubridate', *Journal of Statistical Software*, 40, pp. 1–25. https://doi.org/10.18637/jss.v040.i03

ICES (2021) 'OSPAR request on the production of spatial data layers of fishing intensity/pressure', Report of the ICES Advisory Committee [Preprint]. https://doi.org/10.17895/ICES.ADVICE.8297

Irving, R. (2009) The identification of the main characteristics of stony reef habitats under the Habitats Directive: Summary report of an inter-agency workshop 26–27 March 2008, *JNCC Report 432*, JNCC, Peterborough, ISSN 0963-8091. https://jncc.gov.uk/resources/21693da5-7f59-47ec-b0c1-a3a5ce5e3139

JNCC. (2024) Pobie Bank Reef MPA. https://jncc.gov.uk/our-work/pobie-bank-reef-mpa/ (Accessed: 11 November 2024).

JNCC & Scottish Natural Heritage. (2013) Offshore and Inshore Special Area of Conservation Pobie Bank Reef Conservation Objectives and Advice on Operations.

Johnston, C.M., Turnbull, C.G. & Tasker, M.L. (2002) Natura 2000 in UK Offshore Waters: Advice to support the implementation of the EC Habitats and Birds Directives in UK offshore waters. *JNCC Report 325*. JNCC, Peterborough, ISSN 0963-8091. https://hub.jncc.gov.uk/assets/e26cbc67-7339-4cfe-8469-0c00c97811dd (Accessed: 4 July 2025).

Kröger, K. & Johnston, C. (2016) 'The UK marine biodiversity monitoring strategy. Version 4.1'.

Langenkämper, D. *et al*. (2017) 'BIIGLE 2.0 - Browsing and Annotating Large Marine Image Collections', *Frontiers in Marine Science*, 4, p. 83. https://doi.org/10.3389/fmars.2017.00083

Montes, E. *et al*. (2021) 'Optimizing Large-Scale Biodiversity Sampling Effort: Toward an Unbalanced Survey Design', *Oceanography*, 34(2). https://doi.org/10.5670/oceanog.2021.216

NE & JNCC (2010) 'Marine conservation zone project: Ecological network guidance'. https://data.jncc.gov.uk/data/94f961af-0bfc-4787-92d7-0c3bcf0fd083/MCZ-Ecological-Network-Guidance-2010.pdf

Parry, M. & Robertson, M. (2019) Cruise report Survey 1013S: MRV Scotia - Survey of Pobie Bank Reef cSAC 22 August – 7 September 2013. *JNCC Report 636*, JNCC, Peterborough, ISSN 0963-8091. https://jncc.gov.uk/resources/90cd692b-4235-4a61-aea5-973d40b951f4

QGIS Development Team. (2023) 'QGIS'. QGIS Association. Available at: https://qgis.org/ (Accessed: 15 November 2024).

R Core Team. (2023) 'R'. Vienna, Austria: R Foundation for Statistical Computing. Available at: https://www.R-project.org

Robinson, L.A., Rogers, S. & Frid, C.L.J. (2008) 'A marine assessment and monitoring framework for application by UKMMAS and OSPAR – Assessment of pressure and impacts (Contract No. C-08-0007-0027 for JNCC). University of Liverpool and the Centre for the Environment, Fisheries and Aquaculture Science (Cefas).

Schwarz, G. (1978) 'Estimating the Dimension of a Model', *The Annals of Statistics*, 6(2), pp. 461–464.

Scottish Government. (2025) Fisheries Management Measures within Scottish Offshore Marine Protected Areas Coordinates and Restrictions. Scottish Government. https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2025/09/supporting-guidance-fisheries-management-measures-offshore-marine-protected-areas-coordinates-restrictions/documents/fisheries-management-measures-within-scottish-offshore-marine-protected-areas-coordinates-restrictions/fisheries-management-measures-within-scottish-offshore-marine-protected-areas-coordinates-restrictions/govscot%3Adocument/fisheries-management-measures-within-scottish-offshore-marine-protected-areas-coordinates-restrictions.pdf (Accessed: 27 October 2025).

Sola, J. & Griffin, J.N. (2025) 'Resolving the context-dependency of local heterogeneity–diversity relationships across rocky reefs worldwide', *Proceedings of the Royal Society B: Biological Sciences*, 292(2046), p. 20242723. https://doi.org/10.1098/rspb.2024.2723

Stebbing, P. *et al*. (2014) Monitoring and surveillance for non-indigenous species in UK marine waters. Defra Report.

JNCC (archive). (2017) Strategic Environmental Assessment (SEA) Surveys 2005 and 2006 https://webarchive.nationalarchives.gov.uk/ukgwa/20190301183825/http://jncc.defra.gov.uk/page-4738-theme=default (Accessed: 11 November 2024).

Tangye, T. & Stirling, D. (2024) Pobie Bank Reef Marine Protected Area Survey Report (0923S). *JNCC/SGMD Partnership Report 3*. JNCC / Scottish Government's Marine Directorate. https://hub.jncc.gov.uk/assets/dc79a3e7-aa57-4eb4-9c6f-06d92e819f6b (Accessed: 4 July 2025).

Turner, J.A. *et al*. (2016) Epibiota Remote Monitoring from Digital Imagery: Interpretation Guidelines. NMBAQC. https://www.nmbaqcs.org/media/teblpook/nmbaqc_epibiota_interpretation_guidelines_final.pdf

Tyler-Walters, H. *et al.* (2016) Descriptions of Priority Marine Features (PMFs). 406. https://www.nature.scot/sites/default/files/Publication%202016%20-%20SNH%20Commissioned%20Report%20406%20-%20Descriptions%20of%20Scottish%20Priority%20Marine%20Features%20%28PMFs%29.pdf (Accessed: 6 November 2024).

Vasquez, M. *et al*. (2021) EUSeaMap 2021. A European broad-scale seabed habitat map. Technical Report. EMODnet. https://doi.org/10.13155/83528

WoRMS Editorial Board (2024) 'World Register of Marine Species. https://doi.org/10.14284/170

Appendix 1. Glossary

Term	Description
Activity	A human action which may influence the marine environment (e.g. fishing, energy production; Robinson, Rogers & Frid 2008).
Anthropogenic	Caused by humans or human activities; usually used in reference to environmental degradation. (NE & JNCC 2010).
Assemblage	A collection of plants and/or animals characteristically associated with a particular environment that can be used as an indicator of that environment. The term has a neutral connotation and does not imply any specific relationship between the component organisms, whereas terms such as 'community' imply interactions (Allaby 2015).
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on or near the seabed are benthos (e.g. sponges, crabs, seagrass beds).
Biotope	The physical habitat with its associated, distinctive biological communities. A biotope is the smallest unit of a habitat that can be delineated conveniently and is characterised by the community of plants and animals living there.
Community	A general term applied to any grouping of populations of different organisms found living together in a particular environment; essentially the biotic component of an ecosystem. The organisms interact and give the community a structure (Allaby 2015).
Conservation Objective	A statement of the nature conservation aspirations for the feature(s) of interest within a site, and an assessment of those human pressures likely to affect the feature(s)
Epifauna	Fauna living on the seabed surface.
Favourable Condition	When the ecological condition of a species or habitat is in line with the conservation objectives for that feature. The term 'favourable' encompasses a range of ecological conditions depending on the objectives for individual features.
Feature	A species, habitat, geological or geomorphological entity for which an MPA is identified and managed.
Feature Attributes	Ecological characteristics defined for each feature within site-specific Supplementary Advice on Conservation Objectives (SACO). Feature Attributes are monitored to determine whether condition is favourable.
Impact	The consequence of pressures (e.g. habitat degradation) where a change occurs that is different to that expected under natural conditions (Robinson, Rogers & Frid 2008).
Infauna	Fauna living within the seabed sediment.
Joint Nature Conservation Committee (JNCC)	JNCC is the public body that advises the UK Government and devolved administrations on UK-wide and international nature conservation. JNCC has responsibility for nature conservation in the offshore marine environment, which begins at the edge of territorial waters and extends to the UK Continental Shelf (UKCS).

Term	Description
Marine Strategy Framework Directive (MSFD)	The MSFD (EC Directive 2008/56/EC) aims to achieve Good Environmental Status (GES) of EU marine waters and to protect the resource base upon which marine-related economic and social activities depend.
Marine Protected Area (MPA)	A generic term to cover all marine areas that are ‘A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values’ (Dudley 2008).
Non-indigenous Species	A species that has been introduced directly or indirectly by human agency (deliberately or otherwise) to an area where it has not occurred in historical times and which is separate from and lies outside the area where natural range extension could be expected (Eno, Clark & Sanderson 1997).
Priority Marine Feature (PMF)	Priority marine features are habitats and species considered to be marine nature conservation priorities in Scottish waters.
Sentinel Monitoring of long-term trends (Type 1 monitoring)	Objective: to measure rate and direction of long-term change. This type of monitoring provides the context to distinguish directional trends from short-scale variability in space and time by representing variability across space at any one time and documenting changes over time. To achieve this objective efficiently, a long-term commitment to regular and consistent data collection is necessary; this means time-series must be established as their power in identifying trends is far superior to any combination of independent studies (Kröger & Johnston 2016).

Appendix 2. Data preparation and analysis

Epifaunal data preparation

Epifaunal proformas were created by SeaStar Survey Ltd using imagery data collected during the 1220S survey. Analysis of imagery was undertaken in BIIGLE (Langenkämper *et al.* 2017), with epibiota identified and annotated using the 'CATAMI and nested taxonomic naming tree', based on the CATAMI morphological classification scheme (Althaus *et al.* 2015) and with reference to the World Register of Marine Species (WoRMS Editorial Board 2024). Solitary and/or erect species were tagged using point annotations to provide count data, while colonial / massive / turf taxa were tagged with polygons to provide percentage cover data. Encrusting taxa and high density Ophiuroidea beds were not annotated through BIIGLE but were recorded as an estimation of percentage cover.

The PBR 2020 survey aimed to be the first of many in a 'Type 1' sentinel monitoring time series to assess the scale and direction of change in biological communities over time. This means the analysis of imagery and epifauna should maximise the level of taxonomic detail, to improve the chances of detecting change over time. Subsequently, groups with low taxonomic resolution or mixed ecological niches have not been removed, nor have taxa recorded at few stations, though this has been done previously.

The following truncation steps were applied to the final epifaunal abundance proforma:

- Records without biological ID were removed (i.e. 'indetermined ID' and 'biota').
- While transient species (bony fishes, elasmobranchs) were removed, Brachyura were retained as a taxonomic group strongly associated with the benthic environment.
- NMBAQC Epibiota Protocol followed, merging taxa where their identification unlikely at image quality level.
- Taxa easily identified at 'good' or 'excellent' NMBAQC image quality levels were retained as separate records even if limited in number.
- Taxa with a low number of records were merged to a higher taxonomic level record where possible.
- Sea cucumbers were removed due to low abundance and low taxonomic resolution.
- Bivalvia were retained despite low taxonomic resolution due to importance as an ecological indicator.

Numerical and statistical analyses

Data processing was completed using R version 4.3.2 (R Core Team 2023). Truncated data was filtered to 'good' and 'excellent' quality only.

Sample units were calculated using the covstop (Chao & Jost 2012) algorithm, which calculated the number of images required to achieve 70% coverage using the images from each station and three of its neighbouring stations. This method allows a sample unit to be calculated even when a station has a very low number of images available after filtering. The number of images available per station after filtering ranged from 2 to 43 (Figure 13).

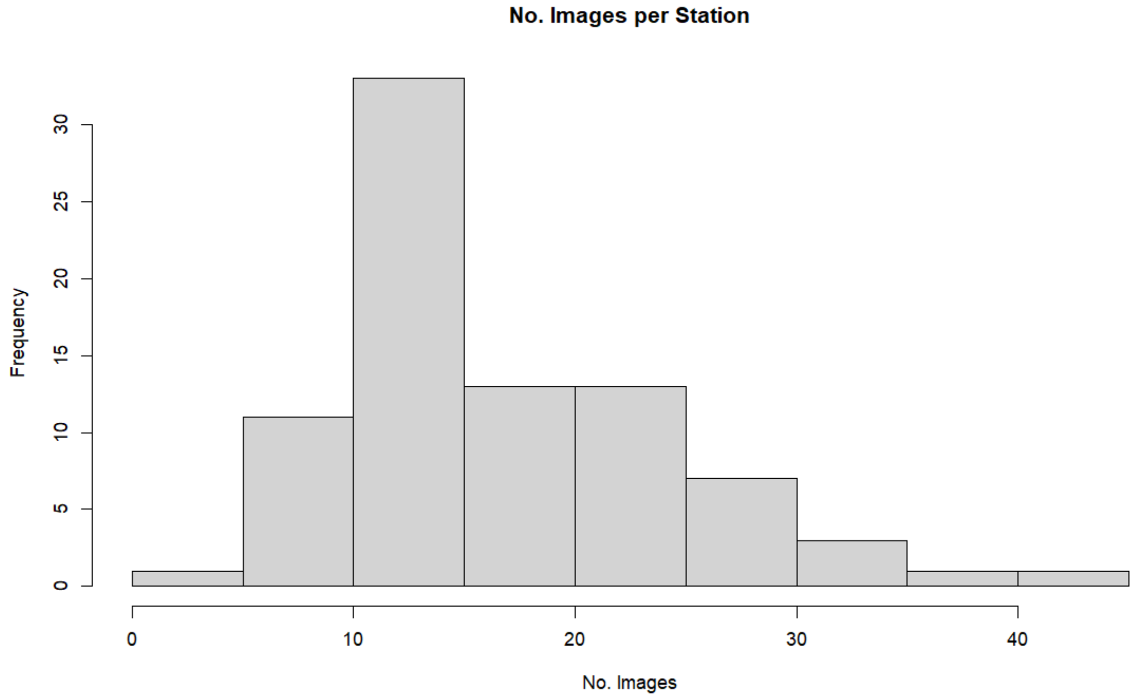

Figure 13. Histogram showing number of images available for analysis per station.

In PRIMER-e (Clarke & Gorley 2015), the count and percentage cover data were combined, the mean calculated per sample unit, and fourth root transformed to limit the dominance of highly abundant species. Habitats were analysed separately.

Appendix 3. Sample coverage calculation

This table displays the number of stations which meet the required number of images for each level of sample coverage considered for use with the covstop algorithm (Chao & Jost 2012).

To achieve a target sample coverage of 0.9, each sample unit station would require 48 images. As no stations met this criterion, the coverage threshold was progressively reduced to 0.8, 0.7, 0.6, and 0.5. This iterative approach aimed to balance the trade-off between sample completeness at individual stations and spatial representation across the study area, as reflected by the proportion of stations excluded from the analysis at each threshold. A final compromise coverage level of 0.7 was selected to optimise both within-station sampling adequacy and overall spatial coverage.

Table 13. Number and proportion of total stations with required quantity of images to meet varying levels of sample coverage, calculated using three nearest neighbour stations.

Sample coverage	No. images required per sample unit	No. stations with sufficient imagery	Proportion of total stations (%)
0.9	48	0	0
0.8	22	23	28
0.7	14	54	65
0.6	10	74	89
0.5	6	82	99

Although 35% of stations within the PBR region did not contain enough images to meet the 0.7 sample coverage threshold, this loss was considered acceptable to maintain a reasonable level of sampling completeness.

Appendix 4. Non-indigenous species lists

Table 14. Taxa listed as non-indigenous species (present and horizon) which have been selected for assessment of Good Environmental Status in GB waters under MSFD Descriptor 2 (Stebbing *et al.* 2014).

Species name	List	Species name	List
Acartia (Acanthacartia) tonsa	Present	*Alexandrium catenella*	Horizon
Amphibalanus amphitrite	Present	*Amphibalanus reticulatus*	Horizon
Asterocarpa humilis	Present	*Asterias amurensis*	Horizon
Bonnemaisonia hamifera	Present	*Caulerpa racemosa*	Horizon
Caprella mutica	Present	*Caulerpa taxifolia*	Horizon
Crassostrea angulata	Present	*Celtodoryx ciocalyptoides*	Horizon
Crassostrea gigas	Present	*Chama sp.*	Horizon
Crepidula fornicata	Present	*Dendostrea frons*	Horizon
Diadumene lineata	Present	*Gracilaria vermiculophylla*	Horizon
Didemnum vexillum	Present	*Hemigrapsus penicillatus*	Horizon
Dyspanopeus sayi	Present	*Hemigrapsus sanguineus*	Horizon
Ensis directus	Present	*Hemigrapsus takanoi*	Horizon
Eriocheir sinensis	Present	*Megabalanus coccopoma*	Horizon
Ficopomatus enigmaticus	Present	*Megabalanus zebra*	Horizon
Grateloupia doryphora	Present	*Mizuhopecten yessoensis*	Horizon
Grateloupia turuturu	Present	*Mnemiopsis leidyi*	Horizon
Hesperibalanus fallax	Present	*Ocenebra inornata*	Horizon
Heterosigma akashiwo	Present	*Paralithodes camtschaticus*	Horizon
Homarus americanus	Present	*Polysiphonia subtilissima*	Horizon
Rapana venosa	Present	*Pseudochattonella verruculosa*	Horizon
Sargassum muticum	Present	*Rhopilema nomadica*	Horizon
Schizoporella japonica	Present	*Telmatogeton japonicus*	Horizon
Spartina townsendii var. anglica	Present	-	-
Styela clava	Present	-	-
Undaria pinnatifida	Present	-	-
Urosalpinx cinerea	Present	-	-
Watersipora subatra	Present	-	-

Table 15. Additional taxa listed as non-indigenous species in the JNCC 'Non-native marine species in British waters: a review and directory' report by (Eno, Clark & Sanderson 1997) which have not been selected for assessment of Good Environmental Status in GB waters under MSFD.

Species name (1997)	Updated name (2017)
Thalassiosira punctigera	-
Thalassiosira tealata	-
Coscinodiscus wailesii	-
Odontella sinensis	-
Pleurosigma simonsenii	-
Grateloupia doryphora	-
Grateloupia filicina var. luxurians	*Grateloupia subpectinata*
Pikea californica	-
Agardhiella subulata	-
Solieria chordalis	-
Antithamnionella spirographidis	-
Antithamnionella ternifolia	-
Polysiphonia harveyi	*Neosiphonia harveyi*
Colpomenia peregrine	-
Codium fragile subsp. atlanticum	-
Codium fragile subsp. tomentosoides	*Codium fragile* subsp. *atlanticum*
Gonionemus vertens	-
Clavopsella navis	*Pachycordyle navis*
Anguillicoloides crassus	-
Goniadella gracilis	-
Marenzelleria viridis	-
Clymenella torquata	-
Hydroides dianthus	-
Hydroides ezoensis	-
Janua brasiliensis	-
Pileolaria berkeleyana	-
Ammothea hilgendorfi	-
Elminius modestus	*Austrominius modestus*
Eusarsiella zostericola	-
Corophium sextonae	-

Species name (1997)	**Updated name (2017)**
Rhithropanopeus harrissii	-
Potamopyrgus antipodarum	-
Tiostrea lutaria	*Tiostrea chilensis*
Mercenaria mercenaria	-
Petricola pholadiformis	-
Mya arenaria	-

Appendix 5. Marine litter categories

Table 16. Categories and sub-categories of litter items for Sea-Floor (European Commission 2013).

A: Plastic	B: Metals	C: Rubber	D: Glass/ Ceramics	E: Natural products/ Clothes	F: Miscellaneous
A1. Bottle	B1. Cans (food)	C1. Boots	D1. Jar	E1. Clothing/ rags	F1. Wood (processed)
A2. Sheet	B2. Cans (beverage)	C2. Balloons	D2. Bottle	E2. Shoes	F2. Rope
A3. Bag	B3. Fishing related	C3. Bobbins (fishing)	D3. Piece	E3. Other	F3. Paper/ cardboard
A4. Caps/ lids	B4. Drums	C4. Tyre	D4. Other		F4. Pallets
A5. Fishing line (monofilament)	B5. Appliances	C5. Other			F5. Other
A6. Fishing line (entangled)	B6. Car parts				
A7. Synthetic rope	B7. Cables				
A8. Fishing net	B8. Other				
A9. Cable ties					
A10. Strapping band					
A11. Crates and containers					
A12. Plastic diapers					
A13. Sanitary towels/ tampons					
A14. Other					

Related size categories

A: ≤ 5*5 cm = 25 cm^2

B: ≤ 10*10 cm = 100 cm^2

C: ≤ 20*20 cm = 400 cm^2

D: ≤ 50*50 cm = 2500 cm^2

E: ≤ 100*100 cm = 10000 cm^2

F: ≥ 100*100 cm = 10000 cm^2

Appendix 6. Abbreviations

AIC	Akaike Information Criterion
BIC	Bayesian Information Criterion
BIIGLE	Bio-Image Indexing and Graphical Labelling Environment
CATAMI	Collaborative and Automated Tools for Analysis of Marine Imagery
FOV	Field of View
ICES	International Council for the Exploration of the Sea
JNCC	Joint Nature Conservation Committee
MBES	Multibeam echosounder
MHCBI	Marine Habitat Classification of Britain and Ireland
MPA	Marine Protected Area
NIS	Non-Indigenous Species
NMBAQC	North East Atlantic Marine Biological Analytical Quality Control Scheme
nMDS	Non-metric Multidimensional Scaling
PBR	Pobie Bank Reef
PMF	Priority Marine Feature
RV	Research Vessel
SAC	Special Area of Conservation
SGMD	Scottish Government's Marine Directorate
SIMPER	Similarity Percentages analysis
SIMPROF	Similarity Profiles
SNCB	Statutory Nature Conservation Body
WoRMS	World Register of Marine Species

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