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North East of Farnes Deep Marine Conservation Zone (MCZ) Monitoring Report 2016

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Since 2010, offshore MPA surveys and associated reporting have been delivered by JNCC and Cefas through a JNCC/Cefas Partnership Agreement (which remained the vehicle for delivering the offshore survey work funded by MPAG between 2012 and 2020).

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Abbreviations

ANOSIM	Analysis of Similarity
BPI	Bathymetric Position Index
BSH	Broadscale Habitats
Cefas	Centre for Environment, Fisheries and Aquaculture Science
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
EUNIS	European Nature Information System
FOCI	Feature of Conservation Interest
GES	Good Environmental Status
ICES	International Council for the Exploration of the Sea
JNCC	Joint Nature Conservation Committee
MBES	Multibeam echosounder
MCZ	Marine Conservation Zone
MESH	Mapping European Seabed Habitats project
MPA	Marine Protected Area
MPAG	Marine Protected Areas Group
MSFD	Marine Strategy Framework Directive
NIS	Non-Indigenous Species
NMBAQC	North East Atlantic Marine Biological Analytical Quality Control Scheme
nMDS	Non-metric Multidimensional Scaling
OSPAR	The Convention for the Protection of the Marine Environment of the North East Atlantic
PSA	Particle Size Analysis
PSD	Particle Size Distribution
ROG	Recommended Operating Guidelines
RV	Research Vessel
SACFOR	Superabundant-Abundant-Common-Frequent-Occasional-Rare scale
SACO	Supplementary Advice on Conservation Objectives
SAD	Site Assessment Document
SIMPER	Similarity Percentages analysis
SIMPROF	Similarity Profile analysis
SNCB	Statutory Nature Conservation Body
SOCI	Species of Conservation Interest
TOC	Total Organic Carbon
TRI	Terrain Ruggedness Index

Glossary

Definitions signified by an asterisk (*) have been sourced from Natural England and JNCC Ecological Network Guidance (NE & JNCC 2010).

Activity	A human action which may have an effect on the marine environment; e.g. fishing, energy production (Robinson *et al*. 2008).*
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).*
Broadscale Habitats	Habitats which have been broadly categorised based on a shared set of ecological requirements, aligning with level 3 of the EUNIS habitat classification. Examples of Broadscale Habitats are protected across the MCZ network.
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.
EUNIS	A European habitat classification system, covering all types of habitats from natural to artificial, terrestrial to freshwater and marine.*
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.
Features of Conservation Importance (FOCI)	Habitats and species that are rare, threatened or declining in Secretary of State waters.*

Habitats of Conservation Importance (HOCI)	Habitats that are rare, threatened or declining in Secretary of State waters.*
Impact	The consequence of pressures (e.g. habitat degradation) where a change occurs that is different to that expected under natural conditions (Robinson *et al*. 2008).*
Infauna	Fauna living within the seabed sediment.
Joint Nature Conservation Committee (JNCC)	The statutory advisor to Government on UK and international nature conservation. Its specific remit in the marine environment ranges from 12–200 nautical miles offshore.
Marine Conservation Zone (MCZ)	MPAs designated under the Marine and Coastal Access Act (2009). MCZs protect nationally important marine wildlife, habitats, geology and geomorphology, and can be designated anywhere in English and Welsh inshore and UK offshore waters.*
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).*
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.
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 *et al*. 1997).*
Pressure	The mechanism through which an activity has an effect on any part of the ecosystem (e.g. physical abrasion caused by trawling). Pressures can be physical, chemical or biological, and the same pressure can be caused by a number of different activities (Robinson *et al*. 2008).*
Species of Conservation Importance (SOCI)	Habitats and species that are rare, threatened or declining in Secretary of State waters.*
Supplementary Advice on Conservation Objectives (SACO)	Site-specific advice providing more detailed information on the ecological characteristics or 'attributes' of the site's designated feature(s). This advice is issued by Natural England and/or JNCC.

Executive Summary

Under the UK Marine & Coastal Access Act (2009), Defra is required to provide a report to Parliament every six years that includes an assessment of the degree to which the conservation objectives set for Marine Conservation Zones (MCZ) are being achieved. Statutory Nature Conservation Bodies (SNCBs) carry out a programme of MPA monitoring in order to fulfil this objective. Where possible, this monitoring will also inform assessment of the status of the wider UK marine environment.

The SNCB responsible for nature conservation offshore (between 12nm and 200nm from the coast) is the Joint Nature Conservation Committee (JNCC). JNCC and other SNCBs utilise evidence gathered by targeted surveys and site-specific MPA reports in conjunction with other available evidence (e.g. activities, pressures, historical data, survey data collected from other organisations or data collected to meet different obligations). These data are collectively used to make assessments of the condition of designated features within sites, to inform and maintain up to date site-specific conservation advice and produce advice on operations and management measures for anthropogenic activities occurring within the site. This report, as a stand-alone document, **does not** therefore aim to assess the condition of the designated features or provide advice on management of anthropogenic activities occurring within the site. Anthropogenic pressures and their interaction with the data reported on here are considered by SNCBs at a later stage as part of condition assessment and management advice.

This report includes recommendations to inform ongoing improvement and development of sample acquisition, analysis and data interpretation for future surveys and reporting. Site and feature specific indicator metrics are not currently defined for this site. Potential indicators, where identified, will be evaluated, and considered for inclusion in recommendations for future reporting.

The North East of Farnes Deep MCZ is an offshore MPA located off the north Northumberland coast within the 'Northern North Sea' Charting Progress 2 (CP2) sea area. The North East of Farnes Deep MCZ is designated for four Broadscale Habitats (BSH), 'Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments', and one species Feature of Conservation Importance (FOCI), 'Ocean quahog' (*Arctica islandica*). This report provides evidence on the designated features of the site, primarily derived from the first dedicated monitoring survey conducted in 2016, with reference and qualitative comparison to survey data from 2012. The 2016 data will form the first point in a time series, against which change can be monitored through time (Type 1 monitoring; see Kröger & Johnston 2016).

The 2016 data confirmed that the seabed within the North East of Farnes Deep MCZ is extremely heterogeneous. All four designated Broadscale Habitats (BSH), 'Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments', were recorded across the site, with occasional small patches of 'Moderate energy circalittoral rock'. The vast majority of the 2016 grab samples were dominated by sand fractions, with variable proportions of mud and gravel. The sediments within the site exist on a gradient as opposed to being discrete habitat classes (relation to the BSH classes). In particular 'Subtidal sand' and 'Subtidal mud' samples were extremely similar to each other, and variation within the 'Subtidal coarse sediment' and 'Subtidal mixed sediments' classes was very high. A comparison of 2016 sampling data and the site verification habitat map resulted in moderate agreement (62%) between the physical samples and the predicted habitats. This result is unlikely to represent a substantial change in habitat distribution, but likely illustrates the inherent difficulties in mapping highly heterogeneous and interspersed sedimentary BSH habitats. Extent of the BSH is therefore unlikely to be a reliable indicator of change over time within this MCZ. Given that small-scale variation is unquantified and that minor changes in sediment composition can result in a change in BSH membership, such changes should not automatically be interpreted as meaningful (i.e. indicative of a change in condition) in future assessments.

Multivariate analysis of infaunal community data revealed that the variation observed in sediment composition was reflected in the biological assemblages. The infauna from the majority of the stations (67%) belonged to a broad group typical of muddy sands in the North Sea, whilst the remaining smaller groups were dominated to varying degrees by taxa that associate with coarse sediments. There were some differences in community structure between BSH classes, most notably between ‘Subtidal coarse sediment’ and ‘Subtidal sand’ / ‘Subtidal mud’. This was not, however, consistent and communities of the latter BSH were statistically indistinguishable. It is suggested that consideration of the biological communities under two broad groups, ‘muddy sand communities’ and ‘coarse and mixed sediment communities’ would be more ecologically meaningful than BSH classes. A similar trend was observed for the epifauna data derived from still images, where there was a clear split in community structure between ‘Subtidal sand’ and ‘Subtidal coarse sediments’. As mud fractions are difficult to discern from imagery, the two broad groups suggested for the infauna are also likely to be more accurate for describing epifaunal communities.

The non-indigenous polychaete species *Goniadella gracilis* was recorded in both the 2012 and 2016 surveys and the soft-shell clam, *Mya arenaria*, was recorded in one sample collected during the 2012 survey. Marine litter was observed from two images acquired in 2016.

A set of monitoring recommendations, including suggestions for potential future indicators of change, is presented for the designated features within the North East of Farnes Deep MCZ (and other comparable sites).

1 Introduction

North East of Farnes Deep Marine Conservation Zone (MCZ) is part of a network of sites designed to meet conservation objectives under the Marine and Coastal Access Act (2009). These sites will also contribute to an ecologically coherent network of Marine Protected Areas (MPAs) across the North East Atlantic agreed under the Oslo-Paris (OSPAR) Convention and other international commitments to which the UK is a signatory.

Under the UK Marine & Coastal Access Act (2009), Defra is required to provide a report to Parliament every six years that includes an assessment of the degree to which the conservation objectives set for MCZs are being achieved. Statutory Nature Conservation Bodies (SNCBs) carry out a programme of MPA monitoring in order to fulfil this objective. The SNCB responsible for nature conservation offshore (between 12 nm and 200 nm from the coast) is the Joint Nature Conservation Committee (JNCC). Where possible, this monitoring will also inform assessment of the status of the wider UK marine environment; for example, assessment of whether Good Environmental Status (GES) has been achieved, as required under Article 11 of the Marine Strategy Framework Directive (MSFD).

This monitoring report primarily explores data acquired from the first dedicated monitoring survey of North East of Farnes Deep MCZ in 2016. This dataset will form the initial point in a monitoring time series, against which feature condition can be assessed in the future. The specific aims and objectives of the report are discussed in more detail in Section 1.3.

1.1 Site overview

North East of Farnes Deep MCZ is an offshore site in the North Sea, located approximately 55km from the Berwickshire region of the North Northumberland coast and covering an area of 492km^2. It was recommended as an MCZ by the Net Gain regional stakeholder group project in 2011 (previously as 'Rock Unique MCZ') and falls within the wider 'Charting Progress 2' (CP2) area 'Northern North Sea'. The site is neighboured by the Farnes East MCZ to the west and the Swallow Sand MCZ to the east (Figure 1). The site depth ranges between 50m and 100m below Chart Datum; the deepest section of the site runs parallel to the western boundary and the shallowest section is in the south east quarter.

The site was designated[1] for four Broadscale Habitat (BSH) features ('Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments') and one species FOCI; the bivalve *Arctica islandica*, also known as 'Ocean quahog'.

Previous investigations of biological communities within the MCZ identified a range of sponges on the coarse sediment habitats, as well as hydroids, anemones and various polychaete worms. A range of crustacean species including barnacles, amphipods, and squat lobsters were found to be present in relatively large numbers across the extent of the MCZ. Several species of fish were also observed in video samples, including dragonets, hagfish, and flatfish (JNCC 2018a).

Table 1 lists the BSHs and FOCI that have been reported in the Site Assessment Document (SAD) (Net Gain 2011), and the Site Verification Report (Murray *et al*. 2015), alongside the equivalent EUNIS habitat codes.

[1] http://www.legislation.gov.uk/ukmo/2016/28/pdfs/ukmo_20160028_en.pdf [accessed 07/07/2020]

Table 1. North East of Farnes Deep MCZ overview.

Charting Progress 2 Region[2]	Northern North Sea	
Spatial Area (km²)	492	
Water Depth Range (m)	50 to 100m below Chart Datum	
Features Present	**Designated**	**EUNIS Habitat Code**
Broadscale Habitats (BSH)		
Subtidal coarse sediment	✓	A5.1
Subtidal sand	✓	A5.2
Subtidal mud	✓	A5.3
Subtidal mixed sediments	✓	A5.4
Species Feature of Conservation Importance (FOCI)		
Ocean quahog (*Arctica islandica)*	✓	-

[2]http://webarchive.nationalarchives.gov.uk/20141203170558tf_/http://chartingprogress.defra.gov.uk/ [accessed 07/07/2020]

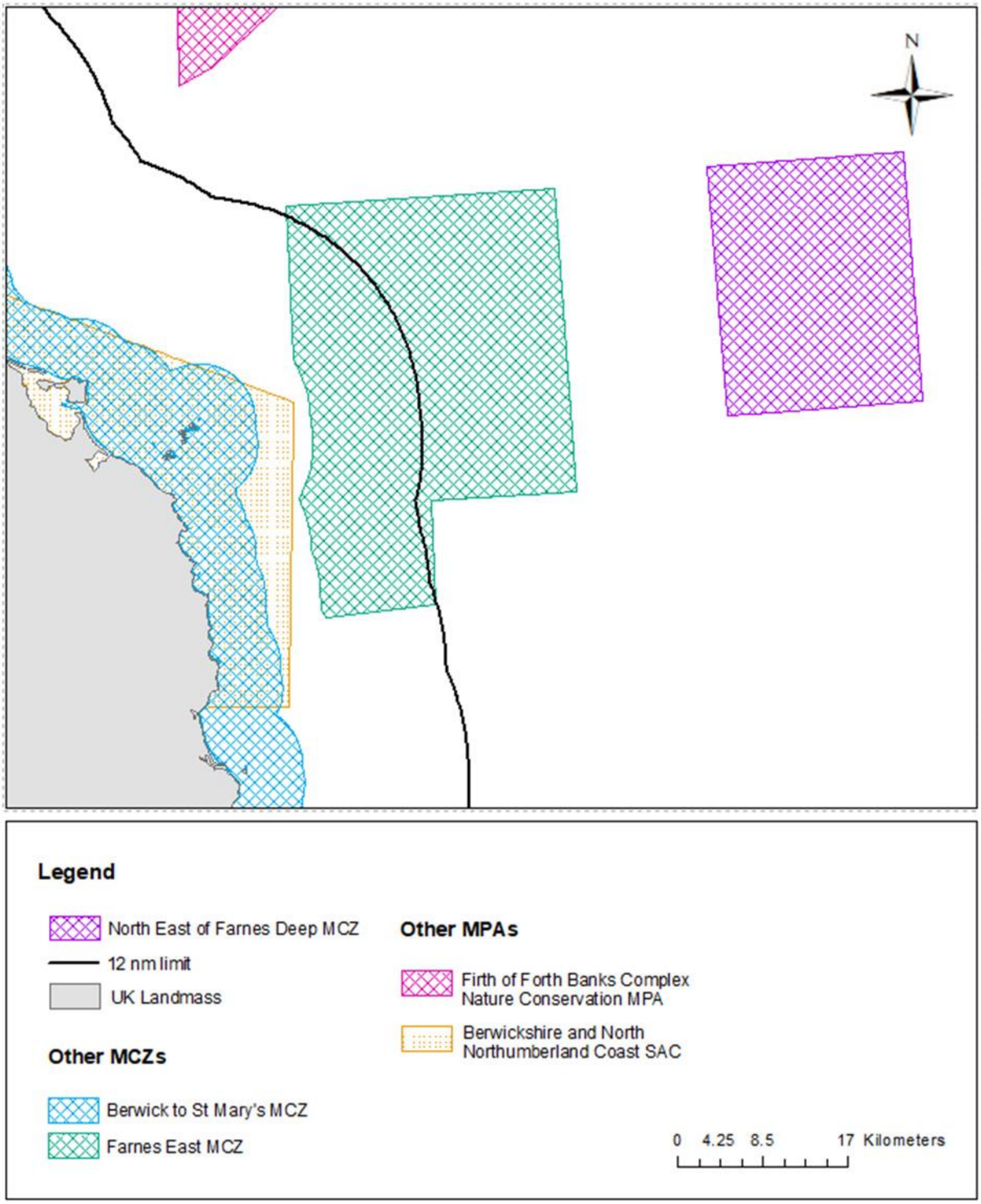

Figure 1. Location of the North East of Farnes Deep MCZ in the context of Marine Protected Areas and management jurisdictions proximal to the site.

1.2 Existing data and habitat maps

A site verification survey was conducted aboard the RV *Cefas Endeavour* (CEND0412) between 7 and 9 March 2012. Samples were collected from 46 stations using a 0.1m^2 Hamon grab, for analysis of sediment particle size and infauna. Sampling stations were positioned within the sediment habitats using a triangular lattice grid, which was overlaid on a predictive habitat map created from expert interpretation of the acoustic datasets (multibeam bathymetry and backscatter). Camera operations were conducted at a sub-set of grab sampling stations, with a total of 18 stations sampled using a towed camera sledge. For further details see Whomersley *et al*. (2012).

A habitat map showing the predicted distribution of BSH within the North East of Farnes Deep MCZ was produced for the Site Verification Report (Murray *et al*. 2015) based on the groundtruthing data from 2012 and multibeam echosounder (MBES) bathymetry data from the Civil Hydrography Programme (2008). The map was produced using object-based image analysis and statistical modelling. Derivatives calculated from MBES backscatter data were slope, roughness, curvature, Bathymetric Position Index (BPI), Terrain Ruggedness Index (TRI), Sobel filter, Aspect and Local Moran's I. These data were segmented into meaningful objects in eCognition v8.7.2, based on the homogeneity of their values and spatial characteristics and using the multiresolution segmentation algorithm. A K-nearest neighbour model was then trained to predict the four BSH sediment types within the site, namely 'Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments'. This map is displayed underlying figures throughout the report. Further information can be found in the Site Verification Report (Murray *et al*. 2015).

1.3 Aims and objectives

1.3.1 High-level conservation objectives

High-level conservation objectives serve as benchmarks against which to monitor and assess the efficacy of management measures in maintaining a designated feature in, or restoring it to, 'favourable condition'.

As detailed in conservation advice for the North East of Farnes Deep MCZ (JNCC 2018b), the conservation objective for the site is that designated features:

a) So far as already in favourable condition, remain in such condition; and
b) So far as not already in favourable condition, be brought into such condition, and remain in such condition.

1.3.2 Definition of favourable condition

Favourable condition, with respect to the habitat features (**'Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments'**), means that:

a) The **extent and distribution** are stable or increasing;
b) The **structures and functions**, including their quality, and the composition of their characteristic biological communities, are such as to ensure that the habitats remain in a condition which is healthy and not deteriorating; and
c) The natural **supporting processes** are unimpeded.

The extent of a habitat feature refers to the total area in the site occupied by the qualifying feature and must also include consideration of its distribution. A reduction in feature extent has the potential to alter the physical and biological functioning of sediment habitat types

(Elliott *et al*. 1998). The distribution of a habitat feature influences the component communities present and can contribute to the condition and resilience of the feature (JNCC 2004).

Structure encompasses the physical components of a habitat type and the key and influential species present. Physical structure refers to topography, sediment composition and distribution. Physical structure can have a significant influence on the hydrodynamic regime operating at varying spatial scales in the marine environment, as well as influencing the presence and distribution of associated biological communities (Elliott *et al*. 1998). The function of habitat features includes processes such as: sediment reworking (e.g. through bioturbation) and habitat modification, primary and secondary production, and recruitment dynamics.

Habitat features rely on a range of supporting processes (e.g. hydrodynamic regime, water quality and sediment quality) which act to support their functioning as well as their resilience (e.g. the ability to recover following impact).

With respect to the designated species FOCI '**Ocean quahog' (*Arctica islandica*)**, this means that the **quality and quantity of its habitat** and the **composition of its population** in terms of number, age and sex ratio are such as to ensure that the population is maintained in numbers which enable it to thrive.

1.3.3 Report aims and objectives

The primary aim of this monitoring report is to explore and describe the designated features within North East of Farnes Deep MCZ, to enable future assessment and monitoring of feature condition. The results presented will be used to develop recommendations for future monitoring.

The specific objectives of this monitoring report are:

1) provide an overarching description of the benthic environment within the site from 2016 data, including any available evidence on seabed features and supporting processes;
2) present evidence on the **extent, distribution, structural** and **functional** feature attributes of **'Subtidal coarse sediment', 'Subtidal sand', 'Subtidal mud' and 'Subtidal mixed sediments'** (see Table 2 for more detail) based on the 2016 data;
3) provide a description of the distribution, abundance and biomass of **Ocean Quahog (*Arctica islandica*)** based on 2012 and 2016 data;
4) conduct a qualitative temporal comparison of 2012 and 2016 grab sample data to evaluate whether sediment composition, BSH classifications, and biological community structure have changed over time;
5) note observations of any habitat or species FOCI not designated as features of the site;
6) present evidence on the abundance and distribution of non-indigenous species (Descriptor 2) and marine litter (Descriptor 10), to satisfy requirements of the MSFD;
7) provide practical recommendations for appropriate future monitoring approaches for both the designated features and their natural supporting processes (e.g. metric selection, survey design, data collection approaches) with a discussion of their requirements.

1.3.4 Feature attributes and supporting processes

To achieve report objective 2, this report will present evidence on feature attributes and supporting processes, as defined in Supplementary Advice on Conservation Objectives (SACO) developed by JNCC for the designated features within North East of Farnes Deep MCZ (JNCC 2018c). It should be noted that it was not possible to address all feature attributes in this monitoring survey, given the extensive nature of the attribute lists for each feature. The feature attributes were therefore rationalised according to JNCC priorities, resulting in a smaller sub-set.

The list of selected feature attributes and supporting processes considered in this report is presented in Table 2, alongside the methods used to address each attribute.

Table 2. Feature attributes and supporting processes addressed to achieve report objective 2.

Feature attribute / supporting process (JNCC 2018c)	Features	Methods
Extent and distribution:		
Extent and distribution	Subtidal coarse sediment Subtidal sand Subtidal mud Subtidal mixed sediments	Review extent and distribution of BSH features and compare with existing habitat map.
	Ocean Quahog (*Arctica islandica*)	Map distribution and abundance from grab samples. Review the extent of suitable habitat.
Structure and function:		
Sediment composition Characteristic biological communities Key and influential species	Subtidal coarse sediment Subtidal sand Subtidal mud Subtidal mixed sediments	PSA analysis derived from seabed sediment samples. Identify patterns in biological assemblages using multivariate analysis. Describe variance in biological assemblage structure within and between BSH. Identify any key structural and influential species.
Non-indigenous species (NIS)	North East of Farnes Deep MCZ	Report and map abundance and distribution of NIS.
Supporting processes:		
Energy/exposure	North East of Farnes Deep MCZ	Present and describe a tidal model.

The 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.

2 Methods

2.1 2016 survey design

Seventy-five stations were identified for sampling prior to the survey. Forty-five sample stations were positioned within the boundaries of the MCZ using expert judgement. Station locations were offset to infill gaps between the 2012 survey sample stations. Seven additional sampling stations were placed within the predicted Broadscale Habitat (BSH) ‘A5.3 Subtidal mud’ to ensure a sufficient number of samples were collected from this Broadscale Habitat. Twenty-three sampling stations from the 2012 survey were revisited; these were selected at random from all stations sampled in 2012.

A single Hamon grab sample was collected from each sample station. At approximately every third station, an underwater camera deployment was undertaken. Stations for camera deployment were selected based on the provisional sediment descriptions taken from the grab samples and were focussed on grab sample stations provisionally assigned to sand and mud.

A total of 73 sediment samples were collected for PSA and infaunal analysis (including three additional samples acquired for groundtruthing acoustic data). Twenty-six stations were sampled with the camera (still image and video data) for epifaunal analysis and broad habitat classification. These stations were selected to cover the observed range of sediment types, based on preliminary assessment of sediments from grab samples. Still images and video data were collected from each station. The 2016 survey design, indicating new stations and revisited 2012 stations, is displayed in Figure 2.

2.2 Data acquisition and processing

The dedicated monitoring survey of the North East of Farnes Deep MCZ was conducted between 24 and 27 May 2016 onboard the RV *Cefas Endeavour*. A detailed account of data acquisition and processing methodologies is available in the survey report (Whomersley *et al*. 2020).

2.2.1 Seabed imagery

Seabed imagery data were collected using a drop camera system consisting of digital stills and video cameras mounted on a frame. All data were collected following MESH Recommended Operating Guidelines (ROG) (Coggan *et al*. 2007).

The digital camera used was a STR Seaspyder Telemetry 18-megapixel digital stills camera. The video footage was captured using an STR SP-IPC_3000a 1080p video camera. Metadata, heading, pitch, roll and GPS position was recorded in real-time using a video overlay. Images of the seabed were acquired every 10–15m over a distance of ~150m. Additional images were collected in heterogeneous areas of BSH and if particular habitats or species FOCI were observed to ensure, as far as possible, that the habitats and species were adequately sampled and accurately identified.

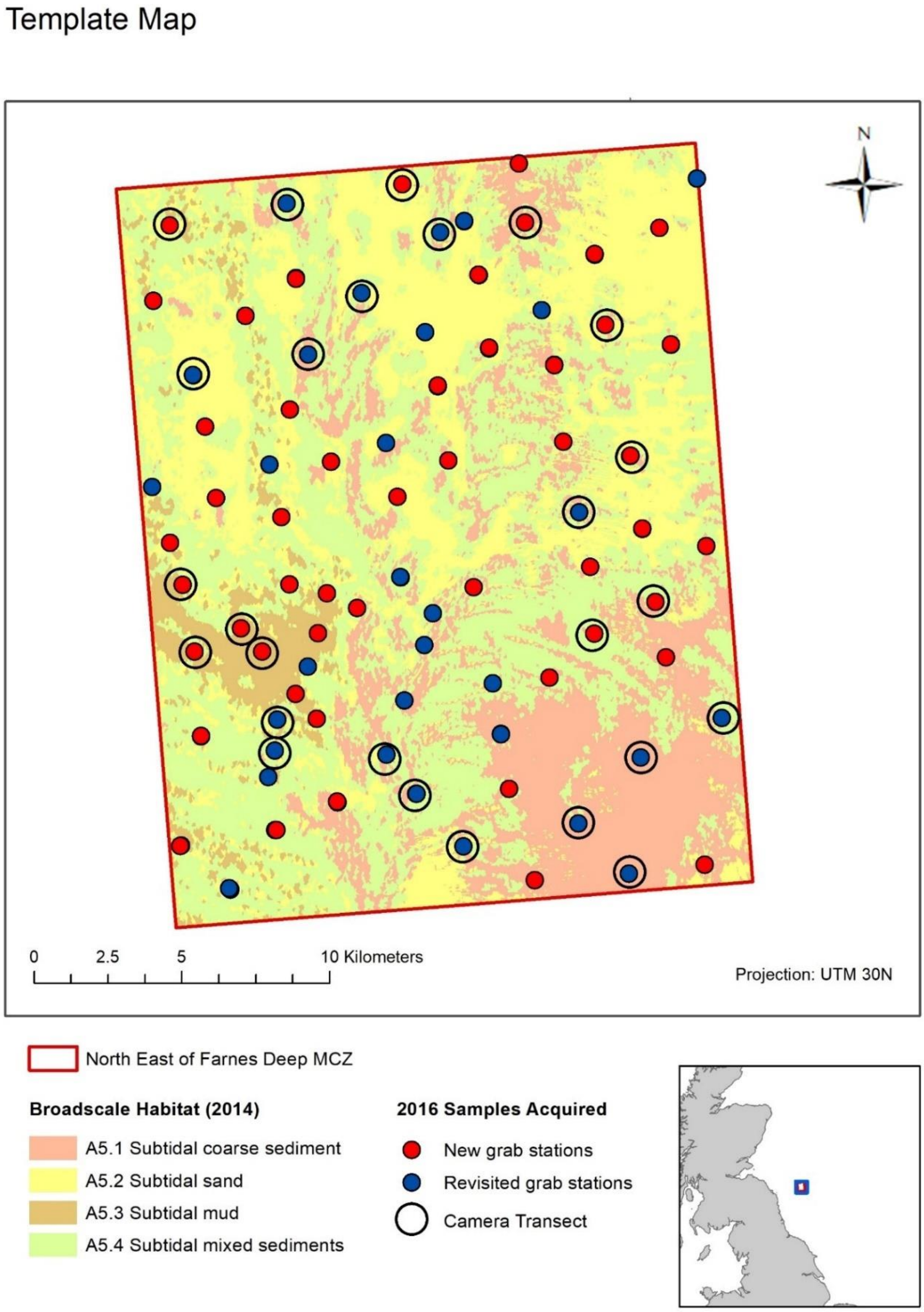

Figure 2. Locations of grab and camera samples collected at North East of Farnes Deep MCZ in 2016.

2.2.2 Seabed sediments

Seabed sediment samples for particle size distribution (PSD) and benthic infauna analyses were collected from a single replicate, using a 0.1m^2 Hamon grab (also known as a 'mini' Hamon grab).

A 500ml sub-sample was taken from each grab sample and stored at -20°C prior to determining the PSD. Sediment samples were processed by Cefas following the recommended methodology of the North East Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme (Mason 2016). The less than 1mm sediment fraction was analysed using laser diffraction and the greater than 1mm fraction was dried, sieved and weighed at 0.5 phi (ϕ) intervals. Sediment distribution data were merged and used to classify samples into sedimentary BSHs.

The faunal fraction was sieved over a 1mm mesh, photographed then fixed in buffered 4% formaldehyde. Infaunal samples were processed to extract all fauna present in each sample. Fauna were identified to the lowest taxonomic level possible, enumerated and weighed (blotted wet weight) to the nearest 0.0001g following the recommendations of the NMBAQC scheme (Worsfold *et al*. 2010).

2.3 Data preparation and analysis

2.3.1 Tidal modelling

Mean and maximum tidal current velocities (m s^{-1}) at the seabed were obtained from a tidal model built for the study area. The depth-averaged model of North East of Farnes Deep MCZ was nested within a larger North Sea model and has been built using an unstructured triangular mesh, using the hydrodynamic software Telemac2D (v7p1). The unstructured mesh was discretised with 292,630 nodes and 571,260 elements. The mesh had a resolution of approximately 6km along the open boundary. In the area of interest, the resolution was refined to approximately 50m. Bathymetry for the model was sourced from the Defra Digital Elevation Model (Astrium 2011). The resolution of the dataset was one arc second (~30m). In the area of the MCZ, the MBES bathymetry was used, gridded to a 2m resolution. The hydrodynamics were forced along the open boundaries using 11 tidal constituents (M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4 and MN4) from the OSU TPXO European Shelf 1/30° regional model [2]. After a spin up period of five days, the model was run for 30 days to cover a full spring-neap cycle. Bed shear stress (N/m^2) was calculated according to Soulsby (1997), based on current speed and local sediment characteristics (derived from the habitat map and sediment samples).

2.3.2 Particle Size Analysis (PSA)

Sediment PSD data (half phi classes) were grouped into the percentage contribution of gravel, sand and mud derived from the BGS-modified version (Long 2006) of classification proposed by Folk (1954). In addition, each sample was assigned to one of four sedimentary BSH:

- Subtidal coarse sediment
- Subtidal sand
- Subtidal mud
- Subtidal mixed sediments

Where sediment samples collected on the 2012 survey corresponded to the location of those acquired on the 2016 survey, they were collectively included in an Entropy analysis, a nonhierarchical clustering method that groups large matrices of PSD datasets into a finite number of groups (Stewart *et al*. 2009), to allow investigation of broad temporal changes (see Section 3.4). For these stations, the full-resolution PSD data (at 0.5 ϕ intervals) were grouped. The optimum number of clusters was achieved when the Calinski–Harabasz (C–H) statistic was at its maximum (Orpin & Kostylev 2006). In addition to this statistic, expert judgement determined that in cases where groups appeared to be very similar, they were numbered as members of the same group, being suffixed with an 'a' or 'b' to show the original groupings.

2.3.3 Infaunal data preparation and analysis

The 2012 and 2016 benthic infauna datasets were reviewed to ensure consistent nomenclature using the WORMS 'match taxa' tool. The data were then truncated according to the truncation steps presented in Annex 2.

The 2016 infaunal abundance data were truncated (following the method described in Annex 2), imported into PRIMER v7 (Clarke and Gorley, 2015) and square root transformed to reduce the dominance of species with higher abundance. Relevant factors and variables (sediment percentage composition, BGS-modified Folk class, BSH membership and year) were assigned to the data prior to analysis.

A Bray-Curtis similarity matrix was generated, following which hierarchical cluster analysis and Similarity Profile (SIMPROF) testing were conducted (using group average linkage) and non-metric multidimensional scaling (nMDS) ordination plots were generated. The results of the cluster analysis were used to derive ecologically meaningful groups within the data. A Similarity Percentage (SIMPER) analysis was conducted to determine which taxa contributed the most to similaity within and dissimilarity between these groups. Analysis of Similarities (ANOSIM) was conducted to determine whether assemblages were different between the different BSH classes. A BEST analysis was conducted using the BIO-ENV routine, to explore the degree to which gravel and mud influenced patterns within the multivariate community data. Sand was removed from the model, as draftsmans plots indicated that this variable was highly negatively correlated with gravel. Depth was removed as it was negatively correlated with gravel, and positively correlated with mud.

The 2012 and 2016 infaunal abundance datasets then underwent a separate truncation to ensure comparability between the two years. This involved merging some taxa at a higher taxonomic resolution. The truncation of the two infaunal datasets reduced the number of taxa from 660 to 579 (see Annex 2). As per the 2016 dataset, the 2012 and 2016 combined dataset was imported into PRIMER v7, the data were square root transformed, and a resemblance matrix and nMDS ordinations were generated. The results were explored further using SIMPER.

The abundance and biomass of ocean quahog (*A. islandica*) individuals were extracted from the main datasets for both 2012 and 2016. The biomass values were separated into 10-gram bin sizes and the number of individuals for each category were calculated and displayed on a bar plot.

2.3.4 Epifaunal data preparation and analysis

Epifaunal community composition was investigated using still images. Only those images which were assessed to be of 'Good' or 'Excellent' quality were used, according to NMBAQC guidance (Turner *et al*. 2016). Of these, five randomly chosen still images from each station were taken forward for analysis, being the minimum number of 'Good' or 'Excellent' stills available for all transects across the site. The field of view for each image was not fixed and different modes of recording abundance were employed for colonial and solitary taxa (percent cover and individual counts, respectively). The SACFOR scale was therefore used to provide a semi-quantitative measure of relative abundance that allows comparisons to be made between all organisms within the community (see Turner *et al*. 2016). In order to retain some information about abundance for community analysis, SACFOR scores were converted to a numerical ordinal scale (6 = Superabundant, 5 = Abundant, 4 = Common, 3 = Frequent, 2 = Occasional, 1 = Rare). The average score of the numerical conversion was adopted for each truncated entry. A full description and an example of the truncation process is presented in Annex 3.

The truncated SACFOR data were imported into PRIMER v7 and analysed. As per the infauna, a Bray-Curtis similarity matrix was generated, following which hierarchical cluster analysis and Similarity Profile (SIMPROF) testing were conducted (using group average linkage) and non-metric multidimensional scaling (nMDS) ordination plots were generated. A SIMPER analysis was conducted to determine which taxa contributed the most to similarity within and dissimilarity between these groups.

2.3.5 Evaluating potential indicators

Any potential candidates for future monitoring of feature condition (e.g. a specific taxon) are evaluated against the criteria provided in
Table 3. These criteria were set out by OSPAR (2012) in advice on the selection of indicators for descriptors of marine biodiversity under the MSFD. They can, however, be broadly applied outside of this context, including in the selection of site or feature specific indicators.

Table 3. OSPAR (2012) state indicator selection criteria (adapted from ICES and UK scientific indicator evaluation).

Criterion	Specification
Sensitivity	Does the indicator allow detection of change against background variation or noise?
Specificity	Does the indicator respond primarily to a specific human pressure, with low responsiveness to other causes of change?
Accuracy	Is the indicator measured with a low error rate?
Simplicity	Is the indicator easily measured?
Responsiveness	Is the indicator able to act as an early warning signal?
Spatial applicability	Is the indicator measurable over a large proportion of the geographical area to which it is to apply?
Management link	Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator (i.e. are the quantitative trends in cause and effect of change well known?)
Validity	Is the indicator based on an existing body or time series of data (either continuous or interrupted) to allow a realistic setting of objectives?
Communication	Is the indicator relatively easy to understand by non-scientists and those who will decide on their use?

2.3.6 Non-indigenous species (NIS)

The raw infaunal and epifaunal data were cross-referenced against a list of 49 non-indigenous target species which have been selected for assessment of Good Environmental Status in UK waters under MSFD Descriptor 2 (Stebbing *et al*. 2014; Annex 4). The list includes two categories: species which are already known to be present within the assessment area (present) and species which are not yet thought to be present but have a perceived risk of introduction and impact (horizon). An additional list of taxa, which were identified as invasive in the 'Non-native marine species in British waters: a review and directory' (Eno *et al.* in 1997) was also used to cross reference against the observed taxa (Annex 4).

2.3.7 Marine litter

Observations of marine litter from imagery data were categorised and recorded according to the MSFD list provided in Annex 5.

3 Results

3.1 Benthic and environmental overview

3.1.1 Tidal model

The tidal currents in the North East of Farnes Deep MCZ were determined to run north or south depending on the state of the tide; the peak flood tide running from north to south and the peak ebb tide running south to north. Tidal currents across the site were predicted to be relatively uniform, with mean current velocities ranging from 0.19ms^{-1} to 0.23ms^{-1}. Maximum tidal velocities ranged from 0.39ms^{-1} to 0.53ms^{-1}, with currents tending to be stronger in the west of the site. The weak current velocities make this site a predominantly low energy environment. The maps in Figure 3 show current conditions (the main direction of tidal flow during the flood phase) as well as mean and maximum velocity over a spring-neap tidal cycle.

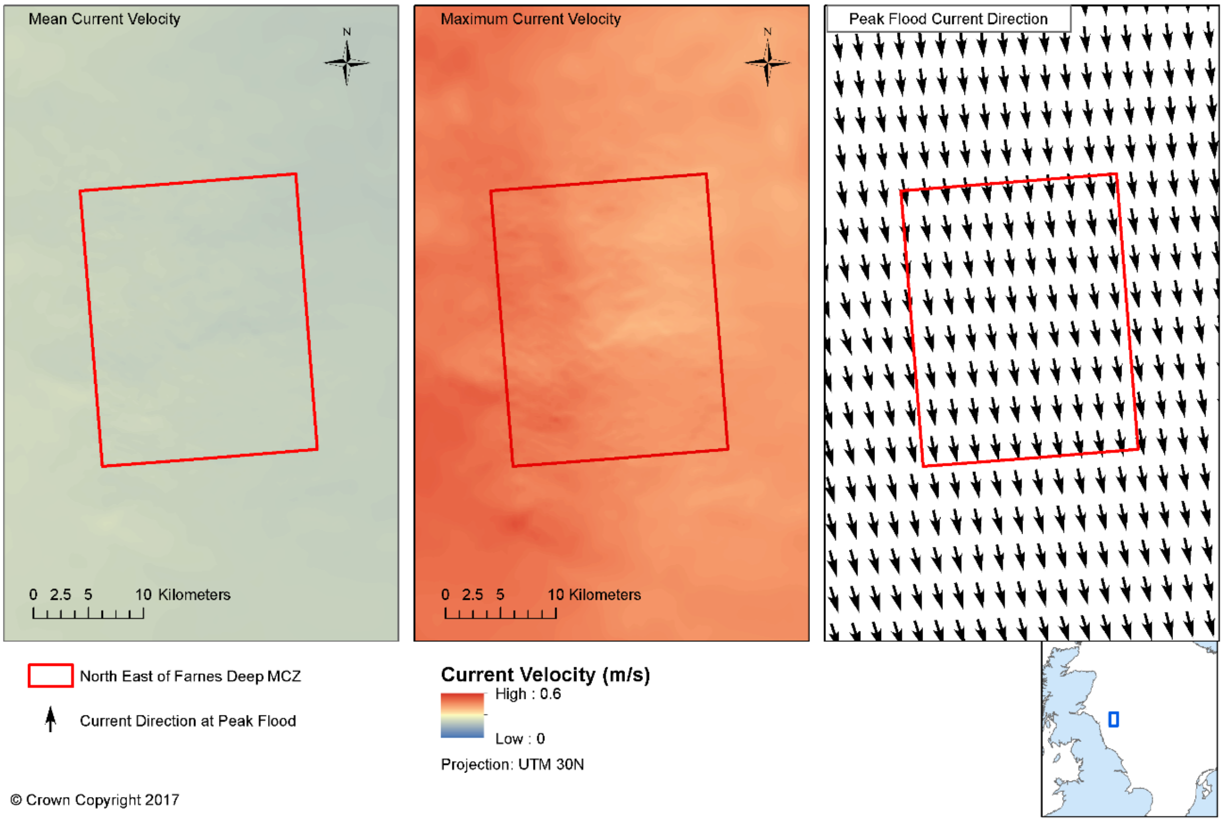

Figure 3. Tidal current velocity model for North East of Farnes Deep MCZ.

3.1.2 Particle Size Distribution (PSD) and Broadscale Habitats (BSH)

PSA showed that the sand fraction dominated the vast majority of the 2016 grab samples, with varying proportions of mud and gravel. Increased gravel percentage contributions were associated with the 'Subtidal coarse sediment' observed in the south eastern corner of the MCZ, and elsewhere in the east and north of the site. Gravel content was generally low or absent in the west of the site. Figure 4 displays the spatial distribution and percentage contribution of the 2016 particle size data.

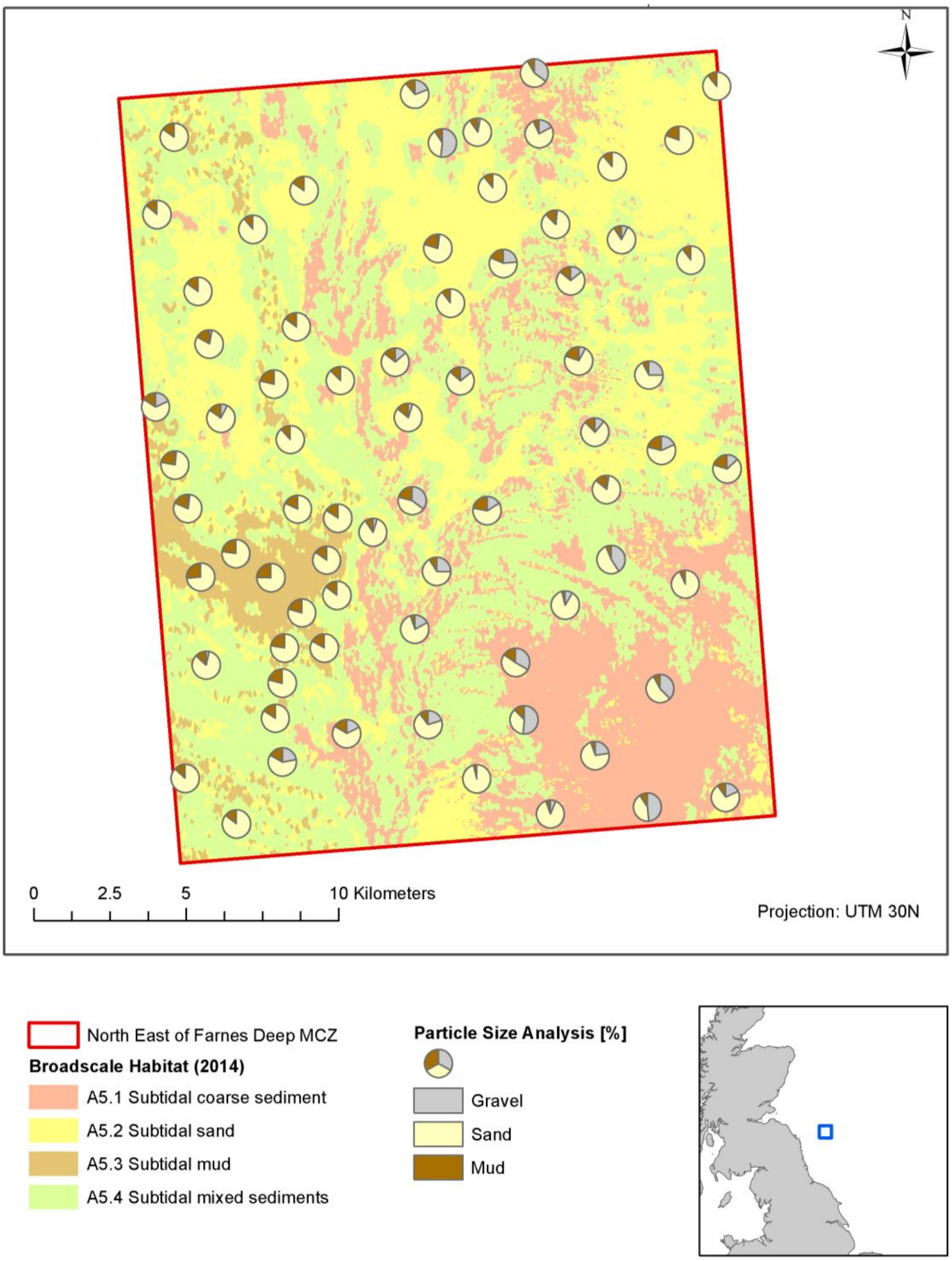

Figure 4. Distribution of sediment fractions at grab sample locations from the 2016 survey at North East of Farnes Deep MCZ overlying the site verification habitat map (Murray *et al*. 2015).

The particle size data have been plotted on a true scale subdivision of the BGS-modified Folk triangle (Long 2006; Folk 1954) in Figure 5. The coloured areas represent sediment BSH.

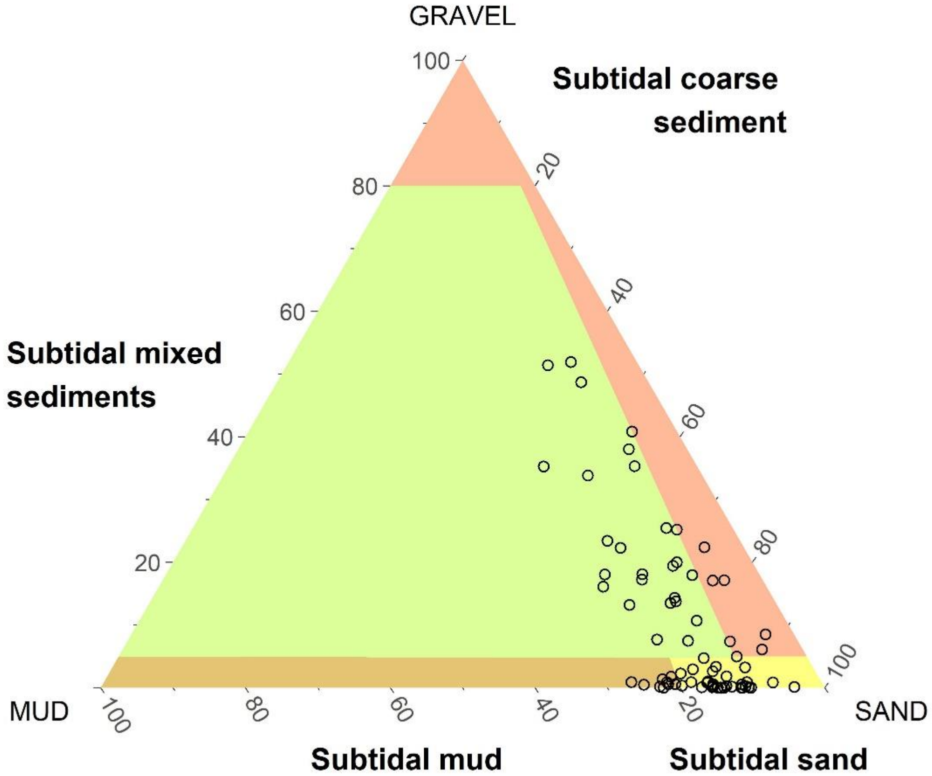

Figure 5. Classification of particle size distribution (half phi) information for each sampling point at North East of Farnes Deep MCZ (2016) into one of the sediment BSHs (coloured areas) plotted on a true scale subdivision of the BGS-modified Folk triangle (Long 2006; Folk 1954).

The majority of the 2016 sediment samples were classified as 'sand and muddy sand' (n = 31), equivalent to the BSH 'Subtidal sand', and 'mixed sediments' (n = 28), equivalent to the BSH 'Subtidal mixed sediments', however it is clear from the distribution of points on the triangle that some points which have been classified as different BSH are extremely similar in terms of sediment composition, with small variations in specific fractions influencing BSH membership. The BSH should therefore not be considered as discrete sediment types.

3.1.3 Broadscale Habitats (BSH)

As previously observed by the site verification survey (Murray *et al*. 2015), the 2016 data showed that the seabed consisted predominantly of a complex mosaic of 'Subtidal coarse sediment', 'Subtidal sand' and 'Subtidal mixed sediments' in varying proportions, with 'Subtidal mud' also recorded.

The shallower areas of the site were dominated by 'Subtidal coarse sediments' which were observed in the south east corner, and also associated with elongate ridges (the majority orientated WNW-ESE and along several more prominent ridges, aligned North–South). An area of 'Subtidal mud' was recorded in the deeper region to the west of the site (corresponding to the site verification habitat map). 'Subtidal sand' and 'Subtidal mixed sediments' BSHs were found to alternate throughout the rest of the site. The four subtidal sediment habitats identified in 2012 were successfully sampled in 2016 with the 'Subtidal mud' feature being targeted to increase confidence in the presence and extent of this habitat. It should be noted, however that 'Subtidal sand' and 'Subtidal mixed sediments' are better represented in the grab datasets, as opposed to ‘Subtidal coarse sediment’ and ‘Subtidal sand’ in the still image datasets.

Comparisons were conducted between the observed distribution of BSH from 2016 samples (as assigned through PSA), and the site verification habitat map (see Figure 6). Some variability in BSH classification was identified between the samples collected in 2016 and the habitat map, however agreement was moderately high, with an accuracy of 62% observed. It should be noted that three of the four habitats present (‘Subtidal coarse sediment’, ‘Subtidal sand’ and ‘Subtidal mixed sediments’) are likely to have similar properties, and very small changes in the proportions of mud, sand and gravel can cause an area to be reclassified as a different BSH. Therefore, although boundaries have been created between the different habitats, these should only be considered indicative. Disagreement between the 2016 sampling points and the site verification habitat map does not necessarily indicate a substantial change in localised sediment composition. The stations where disagreement was observed mainly occurred in areas of predicted ‘Subtidal coarse sediment’ and ‘Subtidal mixed sediments’, particularly where these class predictions were mosaiced on the map (Figure 6). The eastern edges, but not the centre, of the predicted ‘Subtidal mud’ area also showed disagreement. This suggests a gradient of sand and mud content between BSHs.

‘Moderate energy circalittoral rock’ was observed in six still images from the 2016 data, but these areas were not sufficient to warrant a dedicated video segment, and do not correspond to a habitat predicted by the habitat map. Further information on the physical structure and biological communities associated with these areas of rock can be found in Section 3.3.

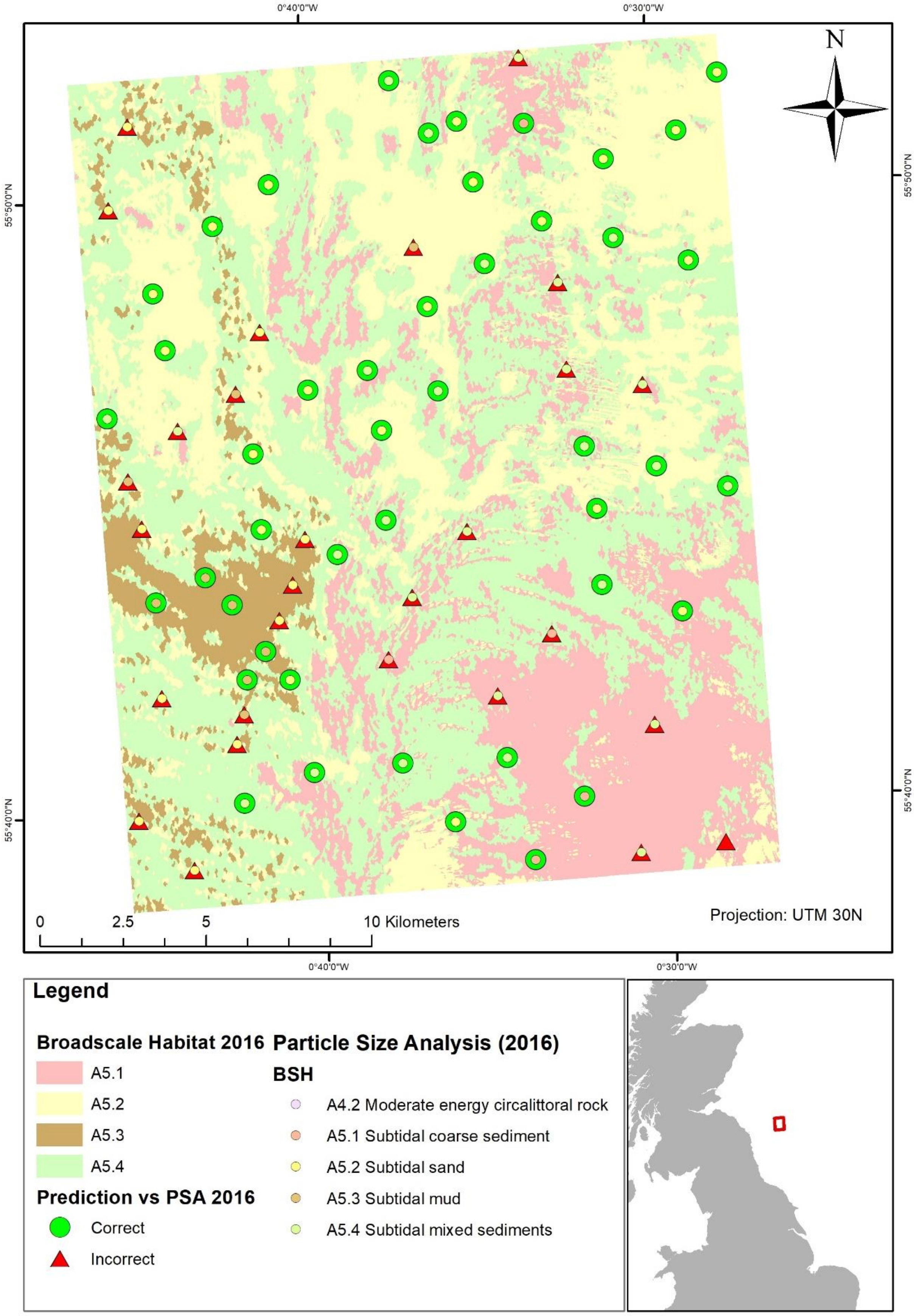

Figure 6. Distribution of BSH features (site verification habitat map, Murray *et al*. 2015) at North East of Farnes Deep MCZ overlain by 2016 sediment samples. Agreement between the habitat map prediction and 2016 sample is indicated.

3.2 Infaunal communities (2016 data)

Hierarchical cluster analysis of the square root transformed infaunal data was initially performed alongside a SIMPROF test, with a significance level of 5%.

This analysis yielded a large number of clusters (illustrated in Figure 8). Detailed exploration of these clusters showed that many were dominated by similar taxa, with minor differences in abundance or assemblage composition driving statistically significant splits in the data.

An nMDS ordination of the infaunal samples overlain with cluster membership is displayed in Figure 7. The moderate stress value (0.14) indicates a potentially useful 2-dimensional plot of the multidimensional data (Clarke & Warwick 2001).

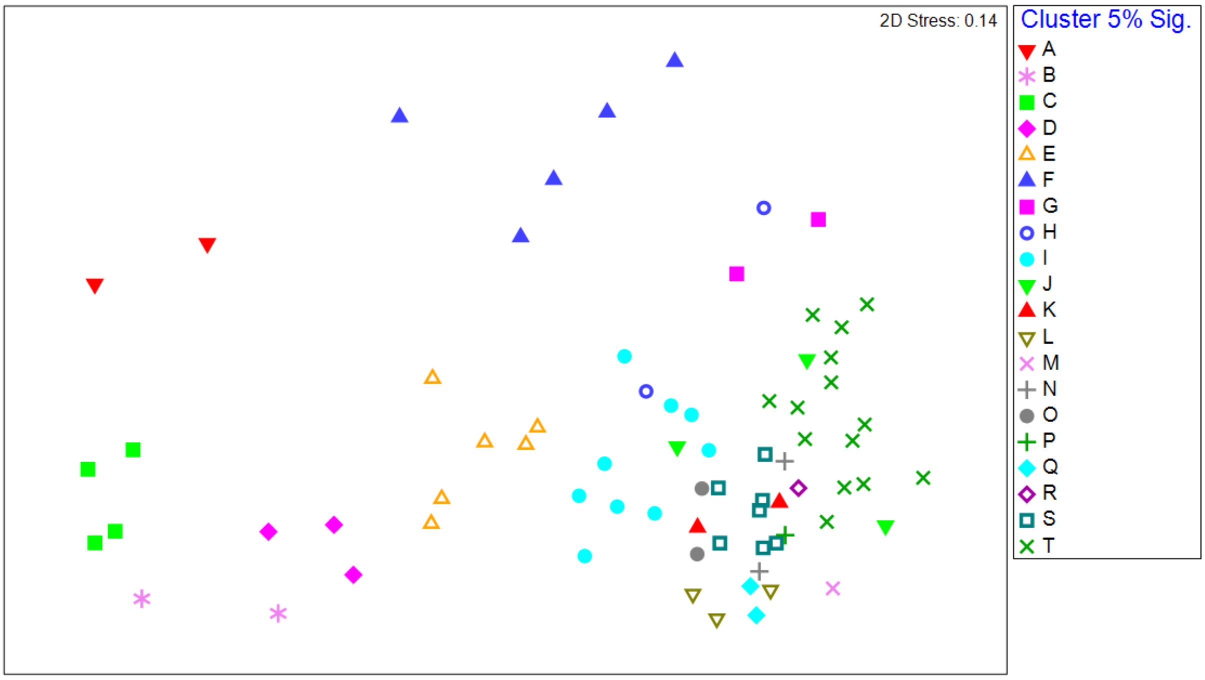

Figure 7. nMDS ordination of square root transformed infauna data (from 0.1m^2 Hamon grab samples taken at North East of Farnes Deep MCZ in 2016), overlain with hierarchical cluster groups derived at the 5% significance level using SIMPROF analysis.

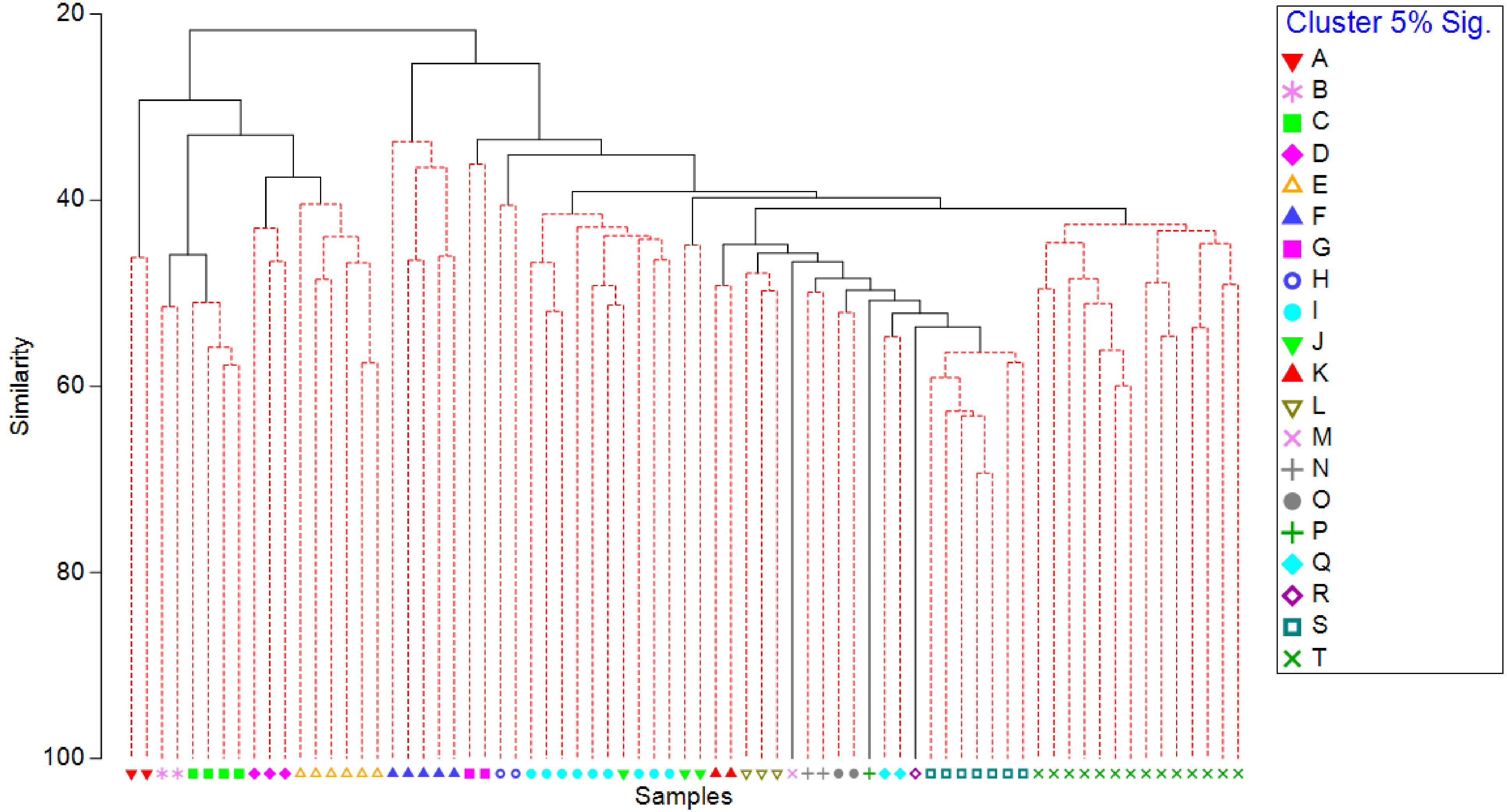

Figure 8. Dendrogram showing statistically significant infaunal clusters derived at 5% similarity using SIMPROF analysis. Samples from North East of Farnes Deep in 2016.

Expert judgement was used to determine a level of similarity (35%) that would allow variation in assemblage composition to be explored at a more ecologically meaningful level. This resulted in six cluster groups and one outlying station (see Figure 9). Forty-nine of the 73 stations (67%) belonged to Group A, whilst group membership was low (two – nine stations) for Groups B to F.

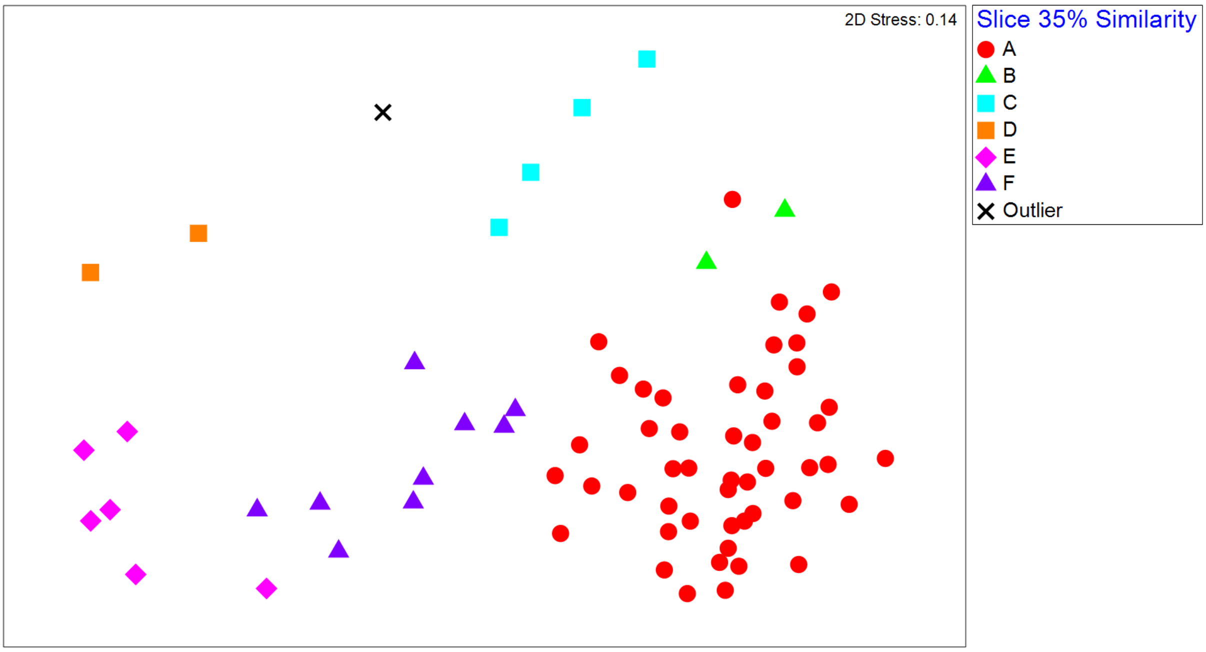

Figure 9. nMDS ordination of square root transformed infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ in 2016), overlain with hierarchical cluster groups derived at 35% similarity.

When compared to the distribution of BGS-modified Folk class membership (Figure 13), these cluster groups follow a similar pattern, indicating that infaunal assemblages are driven (at least in part) by variance in sediment composition.

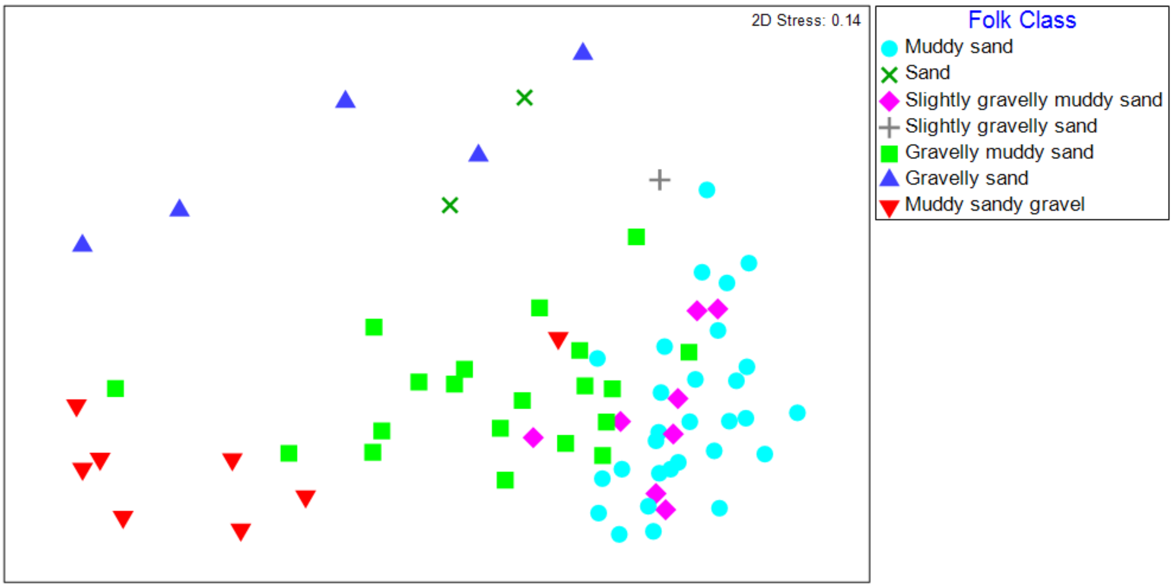

Figure 10. nMDS ordination of square root transformed infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ in 2016), overlain with BGS-modified Folk sediment class membership.

SIMPER analysis was performed on the infaunal dataset, using the 35% similarity cluster grouping as a factor. Similarity within the cluster groups was moderate (36 – 49%) and dissimilarity between groups was high (67 – 88%). The ten highest contributors to within-group similarity are listed in Table 4, alongside sediment characteristics and BSH membership.

The SIMPER results support the existence of a main infaunal group (Group A), as part of a wider assemblage gradient driven by variation in sediment composition.

Group A samples were dominated by sand but were highly variable in terms of the mud (8.59 – 26.26%) and gravel (0.01 – 35.30%) fractions. According to the BGS-modified Folk classification, the group contains sediments described as ‘muddy sand’, ‘slightly gravelly muddy sand’, ‘slightly gravelly muddy sand’, ‘gravelly muddy sand’ and ‘muddy sandy gravel’. Despite this disparity in sediment composition, the average within-group similarity was moderate. The group was dominated by the common sand-dwelling spionid polychaete *Spiophanes bombyx,* horseshoe worms belonging to the genus *Phoronis,* and the burrowing anemone *Edwardsia claparedii*. The remainder of the top dominant taxa comprised polychaete species typical of muddy sand habitats (*Ampharete falcata, Galathowenia oculata, Spiophanes kroyeri, Scoloplos armiger* and *Paramphinome jeffreysii*), in addition to the bivalve *Thyasira flexuosa* and brittlestars of the family Amphiuridae.

The assemblage composition of Group B (comprising two samples classified as ‘muddy sand’ and ‘gravelly muddy sand’) was extremely similar to Group A, although with a notable contribution to similarity from the pea urchin *Echinocynamus pusillus*, which exhibits a preference for coarse sand and gravel (Lumbis 2008), in addition to the amphipod *Autonoe longipes* and the bivalve *Ennucula tenuis.*

Group C comprised ‘sand’ and ‘gravelly sand’ and, whilst primarily dominated by *S. bombyx* and other taxa characteristic of Groups A and B, exhibited a higher dominance by the pea urchin *E. pusillus*. This reflects the lower median mud and higher median gravel content when compared with Group A. The amphipod *Urothoe elegans*, the bivalve *Cochlodesma praetenue* and the polychaete *Glycera lapidum* were also present in the top dominating taxa.

The assemblage composition of Groups D, E and F (comprising ‘gravelly sand’, ‘gravelly muddy sand’ and ‘muddy sandy gravel’) reflected the more pronounced influence of the (generally) higher gravel content, with hard substrate attached species such as the tube-dwelling polychaete *Hydroides norvegica* and the mollusc *Leptochiton asellus* appearing in the dominant taxa, alongside free-living but gravel-associated *E. pusillus* and brittlestar *Ophiactis balli*.

The spatial distribution of the cluster groups within the site is displayed in Figure 11. Group A, the main group, occurred across the majority of site (with the exception of the south eastern area) being entirely dominant in the east of the site. The cluster groups associated with the more gravelly sediments dominated the south east of the site, and were interspersed with Group A in the centre and north east of the site.

Table 4. SIMPER analysis results: ten highest infaunal contributors to similarity within cluster groups (>35% similarity) at North East of Farnes Deep MCZ in 2016.* Average square root abundance. ** Cumulative contribution to within-group similarity. S = No. of taxa, N = No. of individuals, H'= Shannon diversity (loge).

Group A			
Average similarity: 42% n = 49			
Sediment %	**Min**	**Max**	**Median**
Gravel	0.01	35.30	0.90
Sand	56.10	89.82	82.99
Mud	8.59	26.26	15.25
Broadscale Habitats (BSH) Subtidal sand Subtidal mud Subtidal mixed sediments			
	S	**N**	**H'**
Min	24	52	1.97
Max	81	215	4.16
Median	43	103	3.24
Taxon		**Abun***	**Cum.%****
Spiophanes bombyx		3.74	11.26
Phoronis sp.		2.38	19.11
Edwardsia claparedii		2.08	25.49
Ampharete falcata		2.46	31.49
Galathowenia oculata		1.96	36.64
Spiophanes kroyeri		1.74	41.65
Scoloplos armiger		1.18	44.96
Thyasira flexuosa		1.18	48.08
Paramphinome jeffreysii		1.58	51.14
Amphiuridae		1.11	53.98

Group B			
Average similarity: 36% n = 2			
Sediment %	**Min**	**Max**	**Median**
Gravel	0.11	19.47	-
Sand	69.30	89.46	-
Mud	10.44	11.22	-
Broadscale Habitats (BSH) Subtidal sand Subtidal mixed sediments			
	S	**N**	**H'**
Min	31	60	3.06
Max	44	77	3.55
Median	-	-	-
Taxon		**Abun***	**Cum.%****
Spiophanes bombyx		2.98	15.45
Edwardsia claparedii		2.24	28.51
Amphiura filiformis		1.41	36.77
Echinocyamus pusillus		1.93	45.02
Scolelepis korsuni		1.41	53.28
Ampharete falcata		1.00	59.12
Autonoe longipes		1.00	64.96
Ennucula tenuis		1.62	70.8
Oweniidae		1.37	76.64
Phoronis sp.		1.37	82.48

Group C			
Average similarity: 40% n = 4			
Sediment %	**Min**	**Max**	**Median**
Gravel	0.17	17.13	8.99
Sand	75.95	95.73	84.97
Mud	4.11	6.93	6.03
Broadscale Habitats (BSH) Subtidal coarse sediment Subtidal sand			
	S	**N**	**H'**
Min	26	35	3.00
Max	57	124	3.75
Median	32	65	3.20
Taxon		**Abun***	**Cum.%****
Spiophanes bombyx		2.46	10.05
Echinocyamus pusillus		2.36	18.55
Urothoe elegans		1.68	26.55
Paramphinome jeffreysii		1.74	34.30
Edwardsia claparedii		1.54	41.11
Oweniidae		1.39	47.64
Phoronis sp.		1.29	53.48
Cochlodesma praetenue		1.35	59.30
Glycera lapidum		1.29	62.93
Amphiuridae		1.31	66.14

Group D			
Average similarity: 46% n = 2			
Sediment %	**Min**	**Max**	**Median**
Gravel	6.11	22.43	-
Sand	72.17	88.26	-
Mud	5.40	5.63	-
Broadscale Habitats (BSH) Subtidal coarse sediment			
	S	**N**	**H'**
Min	61	120	3.70
Max	70	133	3.91
Median	-	-	-
Taxon		**Abun***	**Cum.%****
Echinocyamus pusillus		3.29	7.33
Hydroides norvegica		2.32	12.51
Laonice bahusiensis		2.32	17.70
Paramphinome jeffreysii		2.12	22.88
Ampelisca spinipes		1.98	27.37
Dialychone dunerificta		2.45	31.86
Leptochiton asellus		2.19	36.35
Timoclea ovata		1.87	40.84
Goniadella gracilis		1.41	44.50
Nemertea		1.57	48.17

Group E			
Average similarity: 49% n = 6			
Sediment %	**Min**	**Max**	**Median**
Gravel	17.97	51.42	36.65
Sand	36.03	72.71	46.96
Mud	8.04	21.18	10.93
Broadscale Habitats (BSH) Subtidal mixed sediments			
	S	**N**	**H'**
Min	75	224	3.54
Max	112	459	3.91
Median	94	295	3.74
Taxon		**Abun***	**Cum.%****
Leptochiton asellus		4.87	6.22
Hydroides norvegica		4.51	11.63
Spirorbinae		4.93	16.06
Paradoneis lyra		3.37	20.17
Ophiactis balli		3.73	24.05
Serpulidae		2.92	27.74
Nephasoma (Nephasoma) minutum		2.72	30.38
Ophiura robusta		2.88	32.86
Timoclea ovata		2.01	35.24
Paramphinome jeffreysii		2.23	37.56

Group F			
Average similarity: 41% n = 9			
Sediment %	**Min**	**Max**	**Median**
Gravel	7.70	51.91	20.02
Sand	38.98	76.95	22.53
Mud	6.20	22.53	10.41
Broadscale Habitats (BSH) Subtidal mixed sediments			
	S	**N**	**H'**
Min	51	111	3.34
Max	73	203	3.85
Median	62	145	3.71
Taxon		**Abun***	**Cum.%****
Galathowenia oculata		3.53	8.65
Hydroides norvegica		2.94	15.37
Paradoneis lyra		2.74	21.85
Spiophanes kroyeri		2.36	27.39
Echinocyamus pusillus		2.00	32.08
Paramphinome jeffreysii		2.41	36.69
Leptochiton asellus		1.92	40.32
Oweniidae		1.55	43.82
Phoronis sp.		1.57	46.65
Notomastus sp.		1.68	49.40

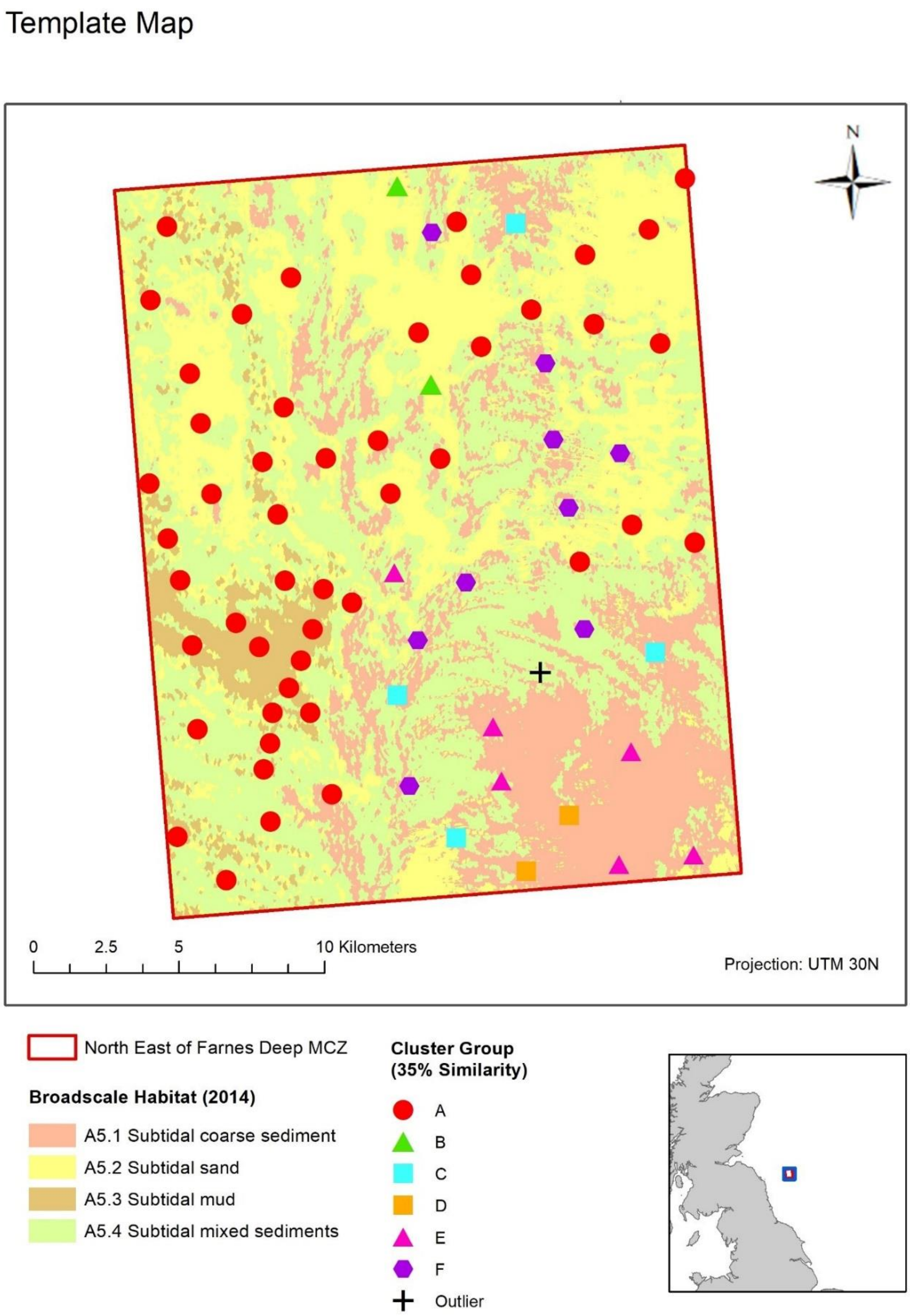

Figure 11. Distribution of cluster groups derived at 35% similarity across the North East of Farnes Deep MCZ (2016).

As predicted based on the results of the cluster and SIMPER analysis, and examination of the nMDS ordinations, BEST analysis revealed that a combination of gravel and mud best explained patterns in infaunal assemblage composition (R = 0.522), although when considered as a single variable, the contribution of gravel was comparable (R = 508), whilst that of mud was low (R = 0.213). It is clear, given the moderate R values generated by the BEST analysis, that other unquantified parameters also influence the infaunal community structure and group membership, (particularly Group A) as illustrated in Figure 12.

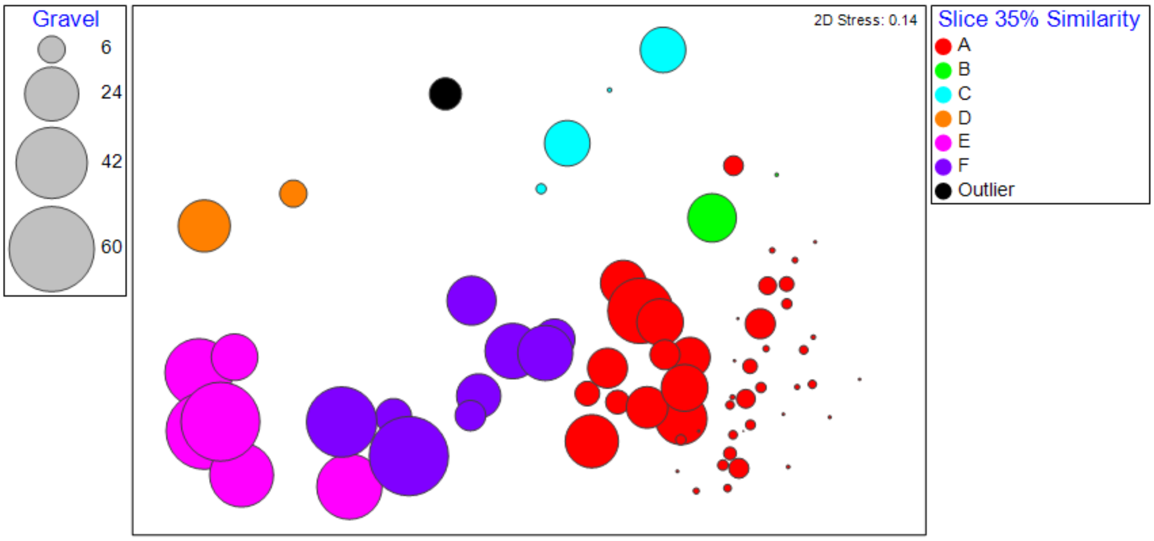

Figure 12. nMDS ordination of square root transformed infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ in 2016), overlain with cluster groups derived at 35% similarity and percentage gravel.

The cluster groups do not correspond to the designated BSH features, as classified from PSA data. There was however a degree of separation between ‘Subtidal coarse sediment’, ‘Subtidal mixed sediments’ and the overlapping ‘Subtidal sand’ and ‘Subtidal mud’ on the nMDS plot (Figure 13).

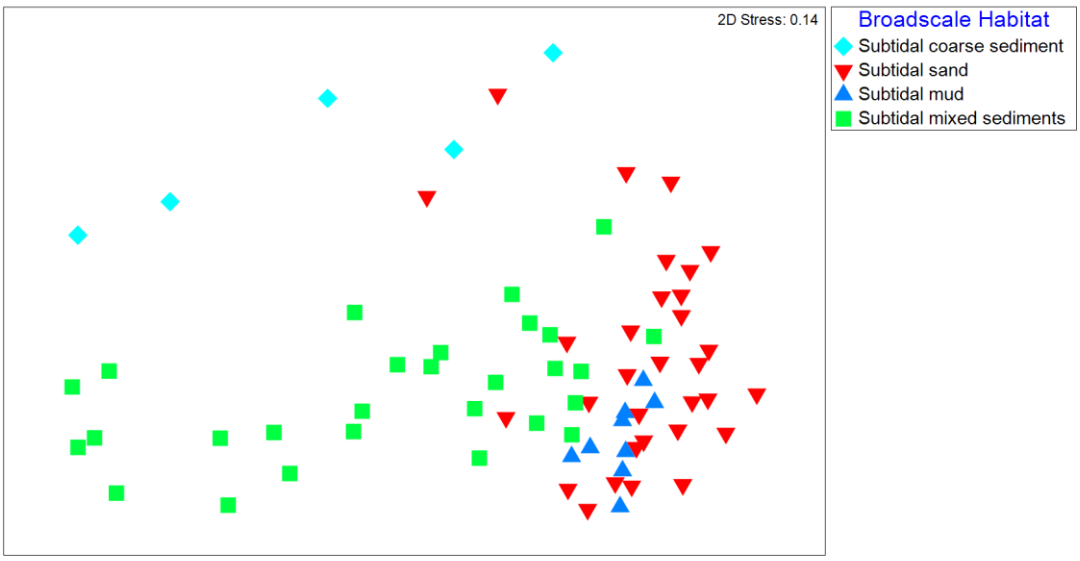

Figure 13. nMDS ordination of square root transformed 2016 infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ), overlain with BSH classes.

The high R values derived from pairwise ANOSIM analysis of infaunal communities between the BSH classes (see Table 5) confirmed that ‘Subtidal coarse sediment’ assemblages were highly distinct from ‘Subtidal mud’ and ‘Subtidal sand’ (although it should be noted there were only five ‘Subtidal coarse sediment’ samples’, therefore these results should be interpreted with caution). ‘Subtidal mixed sediments’ communities were moderately similar to, but statistically distinct from, those of ‘Subtidal coarse sediment’ and ‘Subtidal sand’. ‘Subtidal mud’ and ‘Subtidal sand’ assemblages were extremely similar, with no statistically significant difference found. Whilst statistically distinguishable, the R value for the comparison of ‘Subtidal mixed sediments’ and ‘Subtidal mud’ was extremely low, indicating a negligible difference between classes.

Table 5. Pairwise ANOSIM comparisons of infaunal assemblage composition between Broadscale Habitat (BSH) classes at North East of Farnes Deep MCZ (2016).

Pairwise BSH comparison		R	p
Subtidal coarse sediment	Subtidal mixed sediments	0.502	0.001
Subtidal coarse sediment	Subtidal mud	0.886	0.002
Subtidal coarse sediment	Subtidal sand	0.893	0.001
Subtidal mixed sediments	Subtidal mud	0.153	0.045
Subtidal mixed sediments	Subtidal sand	0.367	0.001
Subtidal mud	Subtidal sand	-0.140	0.925

3.3 Epifaunal communities (2016 data)

Epifaunal video segments and still images from the 2016 survey were each assigned a classification according to the Marine Habitat Classification for Britain and Ireland (JNCC 2015). The classification is presented in Table 6 with example images in Figure 14. It should be noted that ‘Moderate energy circalittoral rock’ was only recorded from seven still images across two stations, and therefore represents small patches of hard substrate on a seabed otherwise dominated by sediments.

Table 6. Marine Habitat Classification for Britain and Ireland (JNCC 2015) classifications for North East of Farnes Deep MCZ and equivalent EUNIS Classification codes.

Designated BSH feature at NEFD	Marine Habitat Classification for Britain and Ireland	Code	EUNIS code	Still images	Video transects
n/a	Moderate energy circalittoral rock	CR.MCR	A4.2	7	-
Subtidal coarse sediment	Circalittoral coarse sediment	SS.SCS.CCS	A5.14	399	15
Subtidal sand	Circalittoral muddy sand	SS.SSa.CMuSa	A5.26	336	11
Subtidal mixed sediments	Circalittoral mixed sediments	SS.SMx.CMx	A5.44	21	-

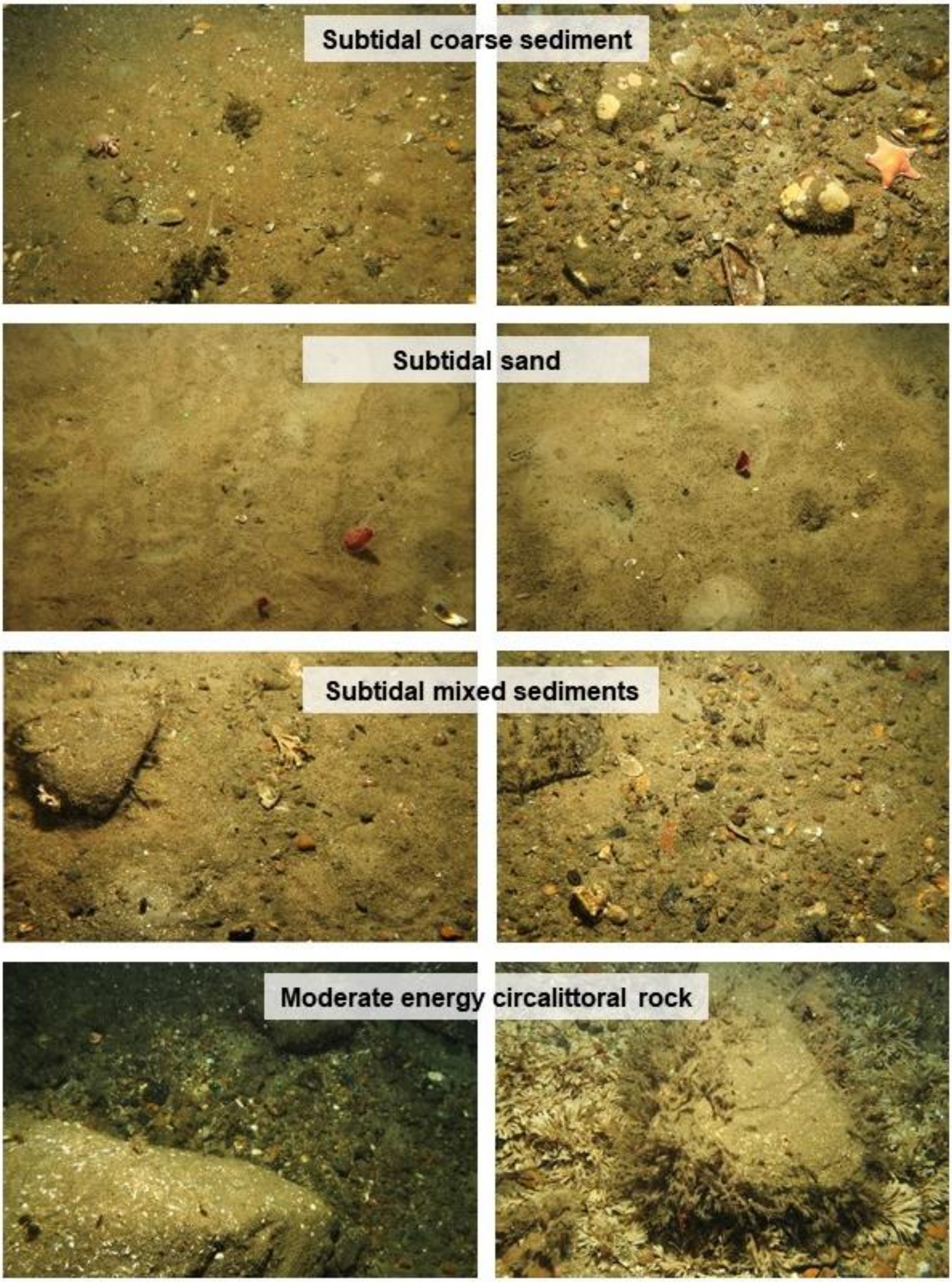

Figure 14. Example images of the habitats discerned from 2016 still and video imagery data at North East of Farnes Deep MCZ.

None of the stills collected during the 2016 survey were classified as 'Subtidal mud'. It should however be considered that some still images visually classified as 'Subtidal sand' are likely to actually comprise 'Subtidal mud', given the difficulty in quantifying mud content from imagery and the proximity of sediment samples determined to comprise 'Subtidal mud'.

Based on the results of the infaunal analysis, where infaunal communities classified as 'Subtidal sand' and 'Subtidal mud' were part of the same assemblage, it is likely that this trend would be repeated in the epifaunal communities. The apparent absence of 'Subtidal mud' from imagery data should therefore not be interpreted as an absence of this BSH.

Only four still images classified as the BSH 'Subtidal mixed sediments' were of good or excellent quality; therefore, this habitat has not been included in the multivariate analysis. The epifauna observed from these stills were Sabellid polychaetes, Chaetopterid parchment worms, hydroids and bryozoans of the family Flustridae.

Predictive modelling of the site prior to the 2012 survey had indicated that a small area of circalittoral rock may be present (although none was recorded on the 2012 survey). Seven still images from the 2016 survey showed a high proportion of cobbles and boulders and were subsequently classified as 'Moderate energy circalittoral rock'. These images were acquired along three camera transects (NEFD10, NEFD12 and NEFD50) and were located in similar water depths (between 64 and 70m below Chart Datum). It should be noted that these discrete patches of cobbles and boulders were extremely limited in extent (not qualifying as separate BSH segments in the video data) and in the context of this dataset should be considered a variant of the 'Subtidal coarse sediment' or 'Subtidal mixed sediments'. The 'Moderate energy circalittoral rock' images were colonised by bryozoans of the family Flustridae, with other hydroids and bryozoans forming a faunal turf on the hard substrate. This turf was inhabited by squat lobsters (Galatheoidea), brittlestars (Ophiuroidea) and sea stars (Asteroidea).

Of the 106 still images collected and described as 'Subtidal coarse sediment' in 2016, 43 were selected for further multivariate analysis based on quality, with 23 different taxa identified. Of the 95 still images described as 'Subtidal sand', 50 were selected for analysis, with 12 different taxa identified. As described in Section 2.3.4, data from five images were combined for each transect.

An initial visual assessment of multivariate assemblage composition was conducted using an nMDS ordination of the averaged SACFOR abundance epifaunal data. The stress level of the ordination is 0.08, indicating a good ordination with no real prospect of a misleading interpretation (Clarke & Warwick 2001).

The nMDS ordination in Figure 15 shows a clear separation between two cluster groups, with an outlying station. This pattern was almost exactly replicated when the 'Subtidal coarse sediment' and 'Subtidal sand' BSH classes were overlain on the ordination.

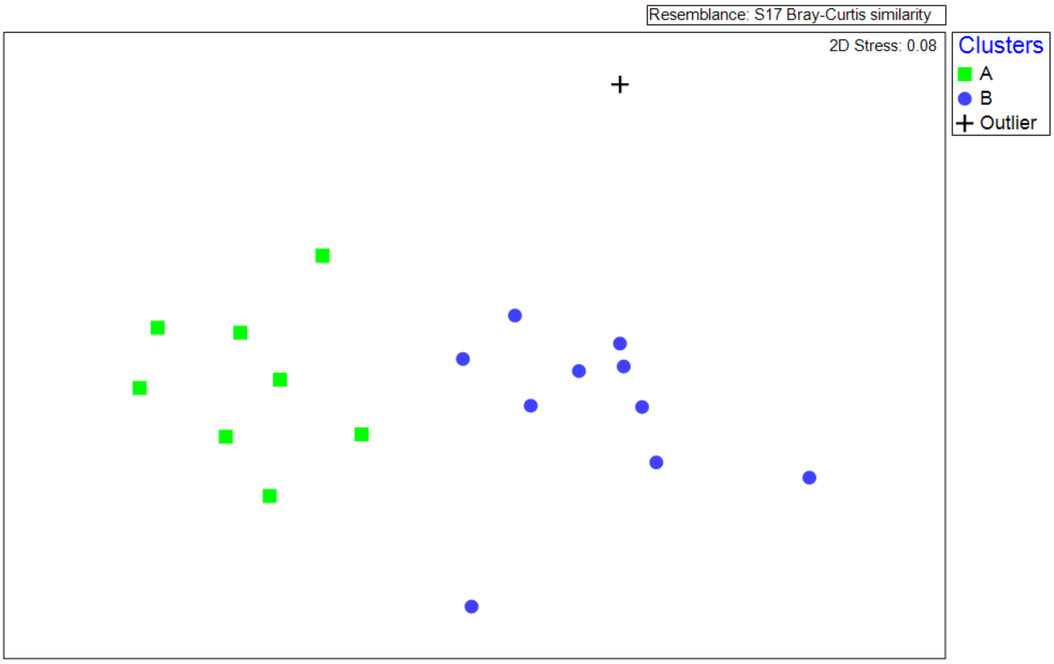

Figure 15. nMDS ordinations showing epifaunal communities (still images) at North East of Farnes Deep MCZ in 2016, with hierarchical cluster membership overlain (as derived by SIMPROF at 5% significance).

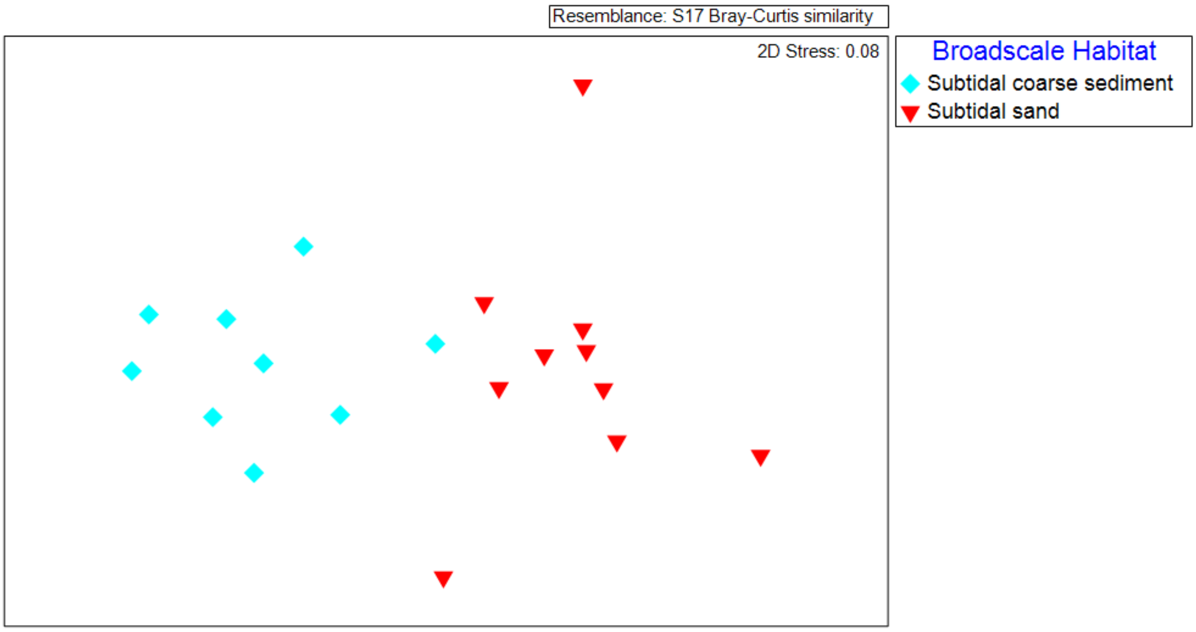

Figure 16. nMDS ordinations showing epifaunal communities (still images) at North East of Farnes Deep MCZ in 2016 with BSH membership overlain.

ANOSIM analysis of the epifaunal community data using BSH membership as a factor also revealed a significant difference between the two BSH groups (Global R = 0.716, $p<0.001$). The differences between these groups were further investigated using SIMPER analysis. Within the 'Subtidal coarse sediment' BSH (equating to Cluster B), similarity was driven by the presence of sessile and encrusting taxa, such as Hydrozoa, Tunicata and Sabellida, as displayed in Table 7. The 'Subtidal sand' BSH (equating to Cluster A) was characterised by a significant contribution by the phosphorescent sea-pen, *Pennatula phosphorea,* which was absent from the 'Subtidal coarse sediment' images (see Table 8).

Although present in both BSH classes, parchment worms of the family Chaetopteridae were notably dominant in 'Subtidal sand', contributing 51.27% to within-group similarity.

Table 7. Epifaunal taxa contributing to similarity within the 'A5.1 Subtidal coarse sediment' BSH at North East of Farnes Deep MCZ in 2016, with average abundance and percentage contribution to within-group similarity.

Taxon	Average within-group similarity = 42%		
	Average abundance (SACFOR)	Contribution to similarity %	Cumulative contribution to similarity %
Tunicata	2.08	22.71	22.71
Sabellida	0.87	17.64	40.35
Flustridae	1.01	13.02	53.37
Chaetopteridae	0.95	12.31	65.68
Paguridae	0.90	11.41	77.1
Decapoda	0.81	5.31	82.41
Munida rugosa	0.92	5.25	87.66
Hydrozoa	0.42	4.27	91.93
Hippasteria sp.	0.50	4.27	96.19
Reteporella	0.53	1.78	97.97
Asteroidea	0.31	1.29	99.26
Echinus sp.	0.36	0.48	99.75
Adamsia palliata	0.18	0.25	100.00

Table 8. Epifaunal taxa contributing to similarity within the 'A5.2 Subtidal sand' BSH at North East of Farnes Deep MCZ in 2016, with average abundance and percentage contribution to within-group similarit.

Taxon	Average within-group similarity = 40%		
	Average abundance (SACFOR)	Contribution to similarity %	Cumulative contribution to similarity %
Chaetopteridae	1.68	51.27	51.27
Pennatula phosphorea	1.50	31.38	82.64
Asteroidea	0.56	16.51	99.16
Paguridae	0.16	0.84	100.00

3.4 Temporal comparison (2012 and 2016)

A total of 21 stations sampled in 2012 were revisited in 2016. The 2016 survey visited the MCZ in May, whereas the 2012 survey was undertaken in March.

3.4.1 Particle Size Analysis (PSA)

As Figure 6 demonstrates, there is limited agreement in BSH membership between those 21 stations which were revisited in 2016, with 11 stations recording a different BSH type and ten with a difference in Entropy sediment group. These differences are shown in Table 9.

Table 9. Changes in Entropy group or BSH across the 11 revisited PSA stations at North East of Farnes Deep MCZ in 2016 where a change was observed. Amber = change, Green = no change.

2012 Station Names	2016 Station Name	2012 Group	2016 Group	2012 BSH	2016 BSH
RU_C_07	NEFD04	3d	3d	A5.1	A5.4
RU_C_12	NEFD05	2a	3c	A5.1	A5.4
RU_C_13	NEFD06	3a	2a	—	A5.4
RU_C_15	NEFD07	1a	1a	—	A5.3
RU_C_19	NEFD10	3a	2a	A5.4	A5.4
RU_C_20	NEFD11	3c	3d	A5.1	A5.4
RU_S_01	NEFD13	3a	2a	A5.1	A5.4
RU_S_09	NEFD16	1a	2a	A5.4	
RU_S_13	NEFD18	1a	1a	A5.3	
RU_S_18	NEFD78	3a	1a	—	A5.4
RU_S_26	NEFD22	1a	2a	—	—
RU_S_19	NEFD19	1a	1a	A5.4	A5.3
RU_S_21	NEFD20	1a	1a	A5.4	

Table 9 shows that the differences between 2012 and 2016 sediment samples principally manifest in a shift from ‘Subtidal coarse sediment’ and ‘Subtidal sand’ to ‘Subtidal mixed sediments’. What is notable from the above is that ten differences are detectable between Entropy groups across the years, whilst only eight differences noted between BSH types. At nine of the ten stations, these differences appear to be associated with the coarser particle size fractions, with no consistent pattern of greater or lesser proportions of coarse material observable in 2016 or 2012 (see Figure 17). The proportion of finer particle sizes were observed to increase between 2012 and 2016, at the four stations which change BSH group from ‘Subtidal coarse sediment’ to ‘Subtidal mixed sediments’ (NEFD4, NEFD5, NEFD11, NEFD13).

Figure 17. Frequency histograms (x axis = %, y axis = μm) showing the differences in particle size distribution across the ten stations at North East of Farnes Deep MCZ where different Entropy groups were assigned in 2012 (red) and 2016 (blue).

3.4.2 Infaunal communities

The jointly truncated infaunal data from the 21 stations visited in both 2012 and 2016 were combined in a resemblance matrix and displayed in Figure 18, overlain by the survey year.

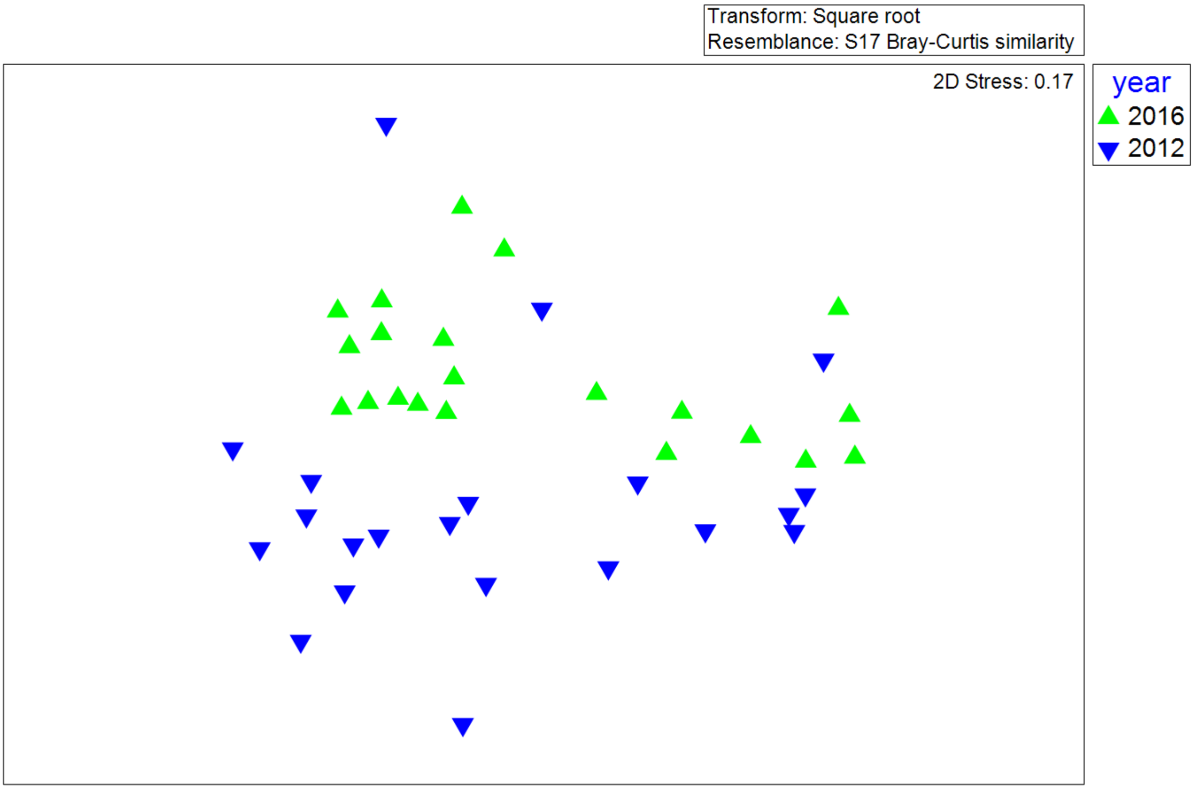

Figure 18. nMDS of Bray-Curtis similarity resemblance across all stations at North East of Farnes Deep MCZ sampled in both 2012 and 2016.

Whilst some overlap is visible in the nMDS ordination, there does appear to be a separation between the two years, which, based on the results of the temporal PSA comparison, does not appear to relate to significant changes in sediment composition.

These differences in community structure between the two years have been further analysed using SIMPER, with the output tabulated in Table 10. Average dissimilarities in contributing taxa between 2012 and 2016 were high within the BSH groups, ranging from 73.73% to 77.30%. The absolute differences in relative abundances are colour coded, highlighting the greater differences apparent in the BSH 'Subtidal mud', likely due in part to low sample numbers (with large increases in 2016 attributed to the increase in sample numbers). More widely, the change in abundances of *Ampharete falcata*, *Spiophanes bombyx* and *Paramphinome jeffreysii* are large across the BSH types in which they contribute. Most notably, the change in abundance of Edwarsiidae (exemplified by no occurance of *Edwardsia claparedii* in 2012, and very limited occurance of Edwarsiidae in 2016) is distinct across all BSH types. It is, however, possible that *E. claparedii* was simply recorded as Edwardsiidae in 2012; therefore no significance should be attached to this change.

Table 10. SIMPER analysis results for the repeat stations by BSH (based on top 8 contributing taxa from 2016) at North East of Farnes Deep MCZ. A colour scale highlights differences in abundance (ABS_Diff) between 2012 and 2016. The scale grades from red (indicating the largest difference) to dark green (indicating the smallest difference).

	A5.1 Subtidal coarse sediment			A5.2 Subtidal sand			A5.3 Subtidal mud			A5.4 Subtidal mixed sediments		
	Average dissimilarity = 77.30			Average dissimilarity = 74.73			Average dissimilarity = 73.73			Average dissimilarity = 75.29		
Species	**2012 Average Abundance**	**2016 Average Abundance**	**ABS_Diff**	**2012 Average Abundance**	**2016 Average Abundance**	**ABS_Diff**	**2012 Average Abundance**	**2016 Average Abundance**	**ABS_Diff**	**2012 Average Abundance**	**2016 Average Abundance**	**ABS_Diff**
Ampharete falcata	-	-	-	0.13	1.97	1.84	0	2.9	2.9	0	0.91	0.91
Amphiura filiformis	-	-	-	0.6	0.68	0.08	-	-	-	0.62	0.38	0.24
Amphiuridae	-	-	-	0.8	1.34	0.54	0	1.72	1.72	-	-	-
Antalis sp.	-	-	-	0.86	0.6	0.26	-	-	-	-	-	-
Cerebratulus	0	1	1	-	-	-	-	-	-	0	1.26	1.26
Cerianthus lloydii	-	-	-	0.3	0.38	0.08	1.41	0	1.41	0.9	0.46	0.44
Chaetozone setosa	-	-	-	0.47	0.6	0.13	-	-	-	-	-	-
Diplocirrus glaucus	-	-	-	0.68	0.47	0.21	2	0.71	1.29	0.71	0.38	0.33
Echinocyamus pusillus	1.99	2.87	0.88	1.1	1.22	0.12	1.73	0.5	1.23	1.49	1.81	0.32
Edwardsia claparedii	0	0.5	0.5	0	2.01	2.01	0	2.45	2.45	0	0.91	0.91
Galathowenia oculata	1.64	1	0.64	1.22	1.63	0.41	-	-	-	1.61	1.89	0.28
Glycera lapidum	0.97	1.57	0.6	-	-	-	-	-	-	0.33	0.87	0.54
Harpinia antennaria	-	-	-	0.38	0.89	0.51	0	1.21	1.21	0	0.49	0.49
Hydroides norvegica	1.9	1.32	0.58	-	-	-	-	-	-	1.17	2.93	1.76
Labidoplax buskii	-	-	-	0.88	1.07	0.19	-	-	-	0.33	0.3	0.03
Lanice conchilega	-	-	-	0	0.75	0.75	0	1.21	1.21	-	-	-
Leptochiton asellus	2.11	1.32	0.79	-	-	-	-	-	-	1.91	2.64	0.73
Lucinoma borealis	-	-	-	0.61	0.68	-	-	-	-	0.62	0.88	0.26
Myriochele danielsseni	0.37	1.12	0.75	0.43	0.38	-	-	-	-	0.74	0.49	0.25
Nemertea	1.65	0.71	0.94	1.14	0.3	0.84	-	-	-	1.24	0.68	0.56
Notomastus	1.67	0.87	0.8	1.07	0.68	0.39	-	-	-	1.54	1.1	0.44
Ophelia borealis	0.47	0.5	-	-	-	-	-	-	-	-	-	-
Oweniidae	1.09	0.71	0.38	1.26	1.07	0.19	2	0	2	-	-	-
Paradoneis lyra	2.03	0.5	1.53	0.76	0.93	0.17	0	1.5	1.5	-	-	-
Paramphinome jeffreysii	1.27	2.12	0.85	0.25	1.63	1.38	0	2.19	2.19	-	-	-
Phoronis sp.	0.33	0.87	0.54	1.64	1.81	0.17	-	-	-	-	-	-
Phyllodoce groenlandica	-	-	-	-	-	-	0	1.41	1.41	-	-	-
Scoloplos armiger	0.79	0	0.79	0.78	1.02	0.24	0	1.41	1.41	-	-	-
Serpulidae	1.53	0	1.53	-	-	-	-	-	-	-	-	-
Sipuncula	0.98	0	0.98	-	-	-	-	-	-	-	-	-
Spiophanes bombyx	0.29	1.41	1.12	0.13	3.15	3.02	0	4.58	4.58	-	-	-
Spiophanes kroyeri	1.19	0.5	0.69	-	-	-	0	1.21	1.21	-	-	-
Thyasira flexuosa	-	-	-	-	-	-	2.65	0.71	1.94	-	-	-
Timoclea ovata	0.4	1.71	1.31	-	-	-	-	-	-	-	-	-
Trichobranchus roseus	-	-	-	-	-	-	2.65	0	2.65	-	-	-
Urothoe elegans	0	1.12	1.12	-	-	-	-	-	-	-	-	-
Verruca stroemia	1.29	0	1.29	-	-	-	-	-	-	-	-	-

Figure 19 to Figure 21 present the bubble plots of the relative abundance for *S. bombyx, A. falcata* and *P. jeffreysii* overlying the nMDS for replicate stations (2012 and 2016). These species appear to be responsible for driving a significant amount of the observable difference between the 2012 and 2016 data.

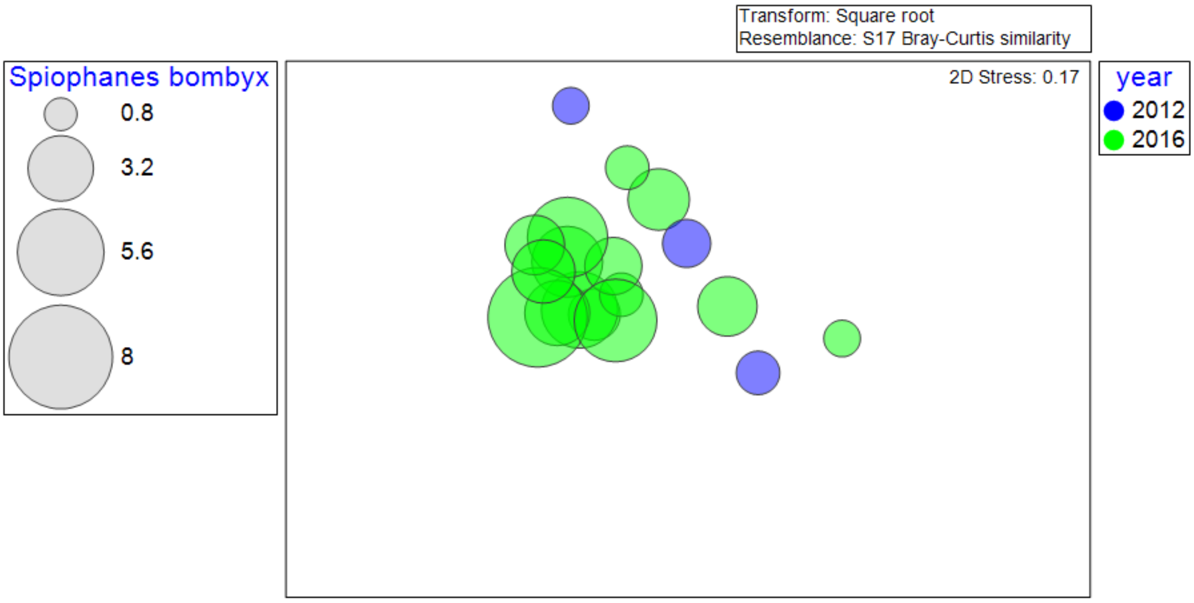

Figure 19. nMDS of infaunal community structures within the North East of Farnes Deep MCZ in 2012 and 2016, with average abundance of *Spiophanes bombyx* overlying.

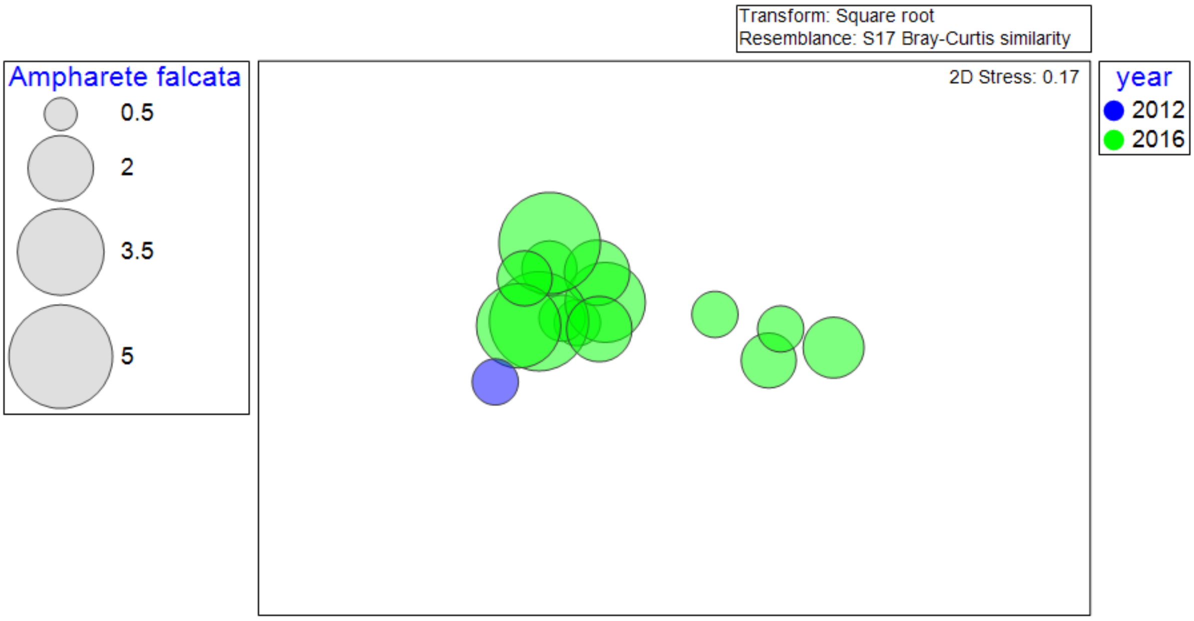

Figure 20. nMDS of infaunal community structures within the North East of Farnes Deep MCZ in 2012 and 2016, with average abundance of *Ampharete falcata* overlying.

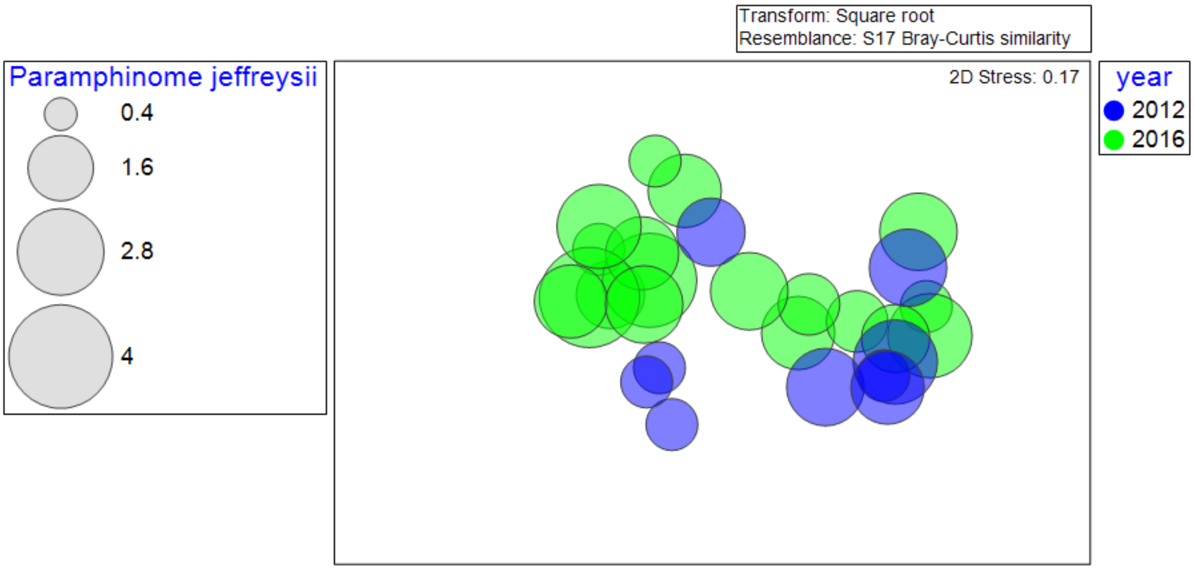

Figure 21. nMDS of infaunal community structures within the North East of Farnes Deep MCZ in 2012 and 2016, with average abundance of *Paramphinome jeffreysii* overlying.

3.5 Habitat Features of Conservation Importance (FOCI)

No undesignated habitat FOCI were observed in the 2016 survey of the North East of Farnes Deep MCZ.

3.6 Species Features of Conservation Importance (FOCI)

3.6.1 Ocean Quahog (*Arctica islandica*)

The FOCI species 'Ocean quahog' (*Arctica islandica)* was recorded in 13 samples in 2012 and 10 samples in 2016 (Figure 22). A total of 28 individuals were collected in 2012 and 13 individuals in 2016.

Figure 22. Ocean quahog (*Arctica islandica)* collected on the 5mm sieve during the 2016 survey (station NEFD22) of the North East of Farnes Deep MCZ.

A. islandica individuals were found across most of the site, with the exception of the shallowest part of the MCZ in the south east, where the habitat 'A5.1 Subtidal coarse sediment' covers a large area. *A. islandica* were almost exclusively associated with cluster group A (Figure 23). Overlying *A. islandica* abundance and the BGS-modified Folk class membership on the 2016 infaunal nMDS ordination (Figure 24) showed that they were recorded at stations with higher proportions of sand and mud, with none recovered in 'gravelly sand' or 'muddy sandy gravel'. It is unclear whether this represents a habitat preference or a sampling artefact.

The species was found in all four sediment BSHs in 2012, but only in 'Subtidal sand' and 'Subtidal mixed sediments' in 2016 (Figure 25).

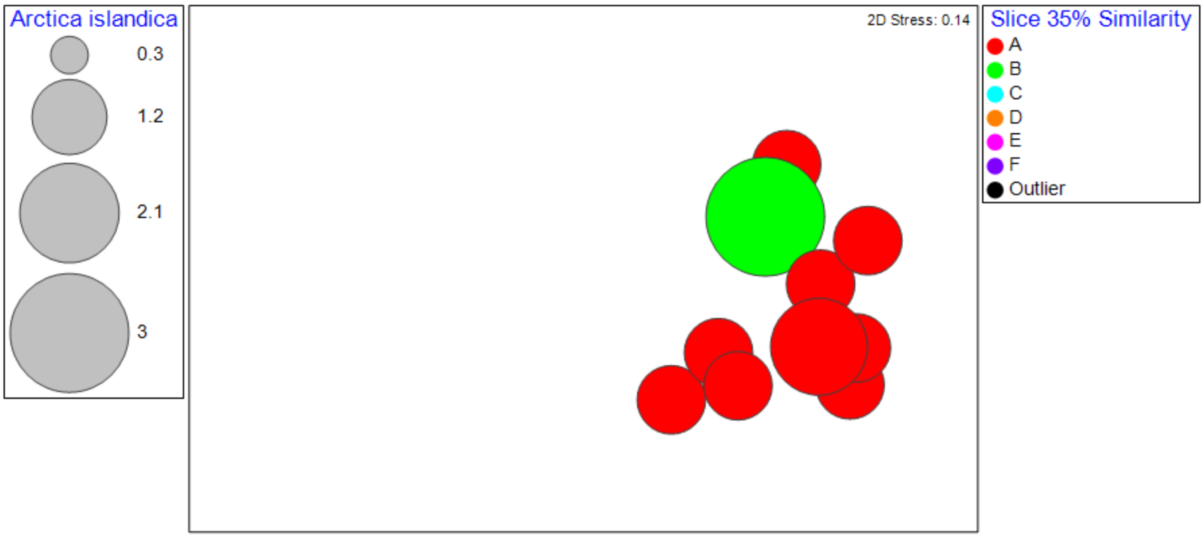

Figure 23. nMDS ordination of square root transformed 2016 infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ), overlain with cluster group membership and *Arctica islandica* average abundance.

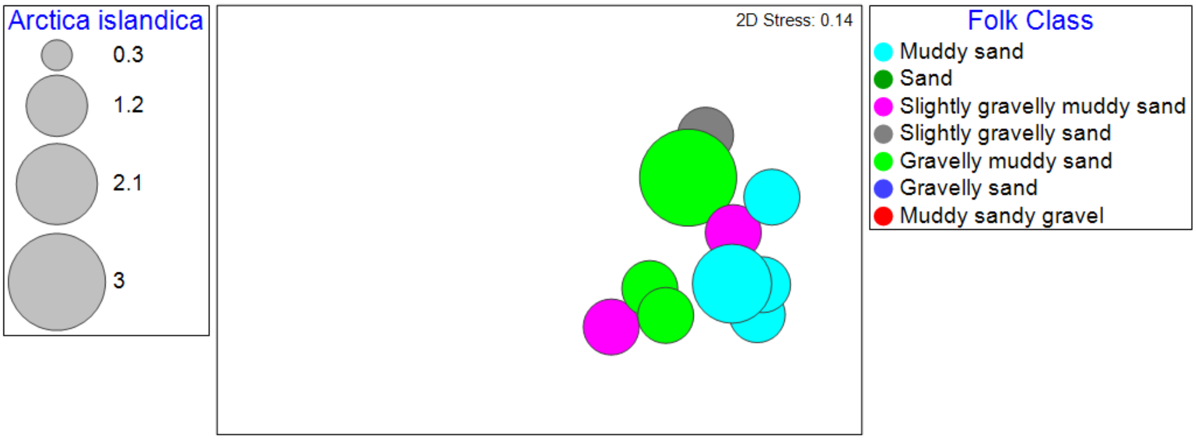

Figure 24. nMDS ordination of square root transformed 2016 infauna data (from 0.1m^2 Hamon grab samples collected at North East of Farnes Deep MCZ), overlain with BGS-modified Folk sediment classes and *Arctica islandica* average abundance.

Most of the individuals collected in the North East of Farnes Deep MCZ area are likely to be juveniles, given the low average weight (Figure 26). Only two larger individuals, potentially sexually mature (12.1g and 72.6g), were collected at two stations in 2016 (Figure 26).

Table 11. *Arctica islandica* total abundance (number of individual) and biomass (g) for the four designated BSHs in the North East of Farnes Deep MCZ. The number in brackets indicates the total number of stations where the species was found.

BSH	2012		2016	
	Abundance	Biomass (g)	Abundance	Biomass (g)
Subtidal coarse sediment	4 (1)	0.24	-	-
Subtidal sand	11 (7)	0.27	8 (7)	84.42
Subtidal mixed sediments	6 (3)	0.04	5 (3)	0.12
Subtidal mud	7 (2)	0.15	-	-

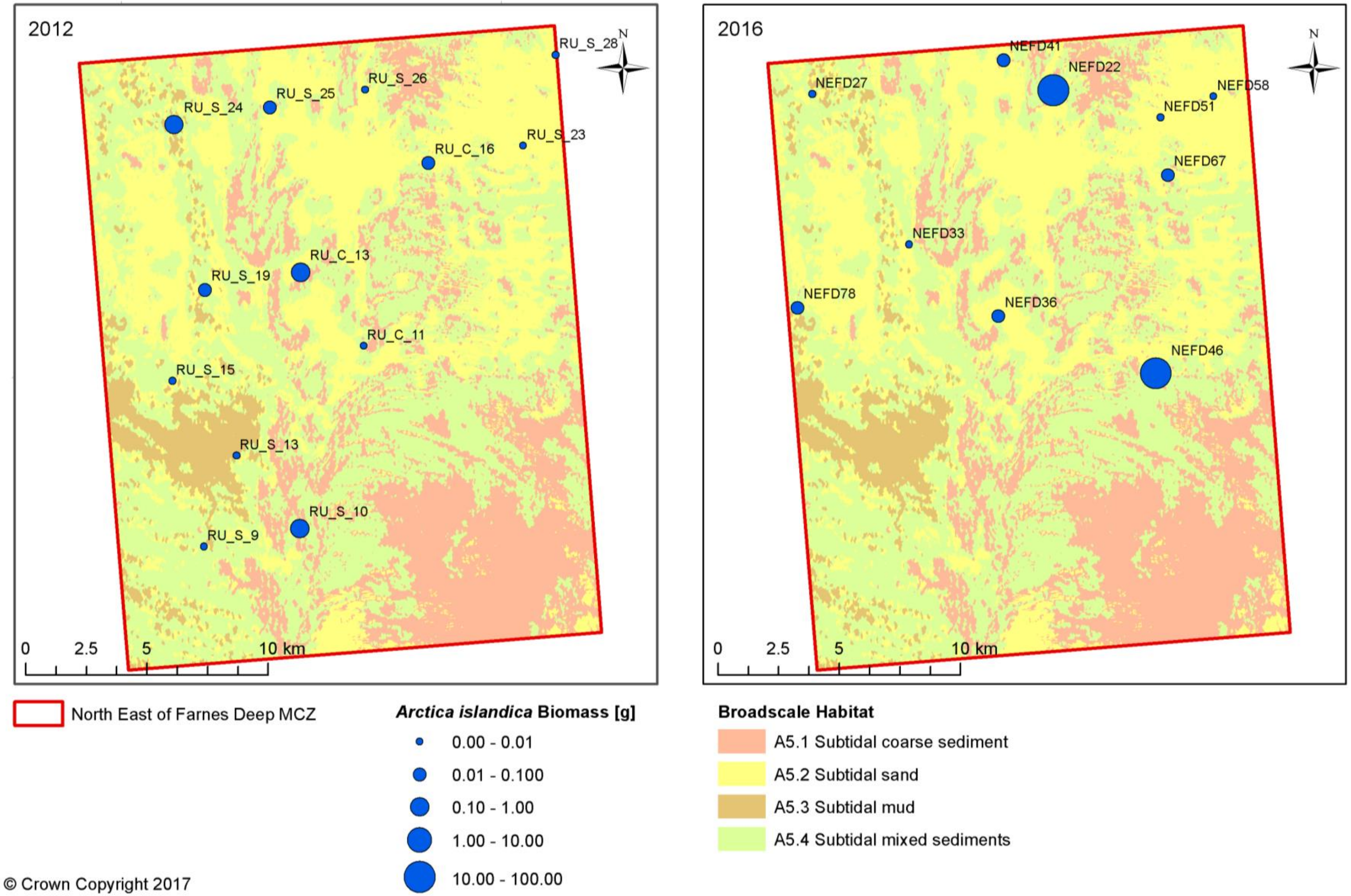

Figure 25. Distribution and total biomass of *Arctica islandica* individuals collected at North East of Farnes Deep MCZ in 2012 and 2016 grab samples.

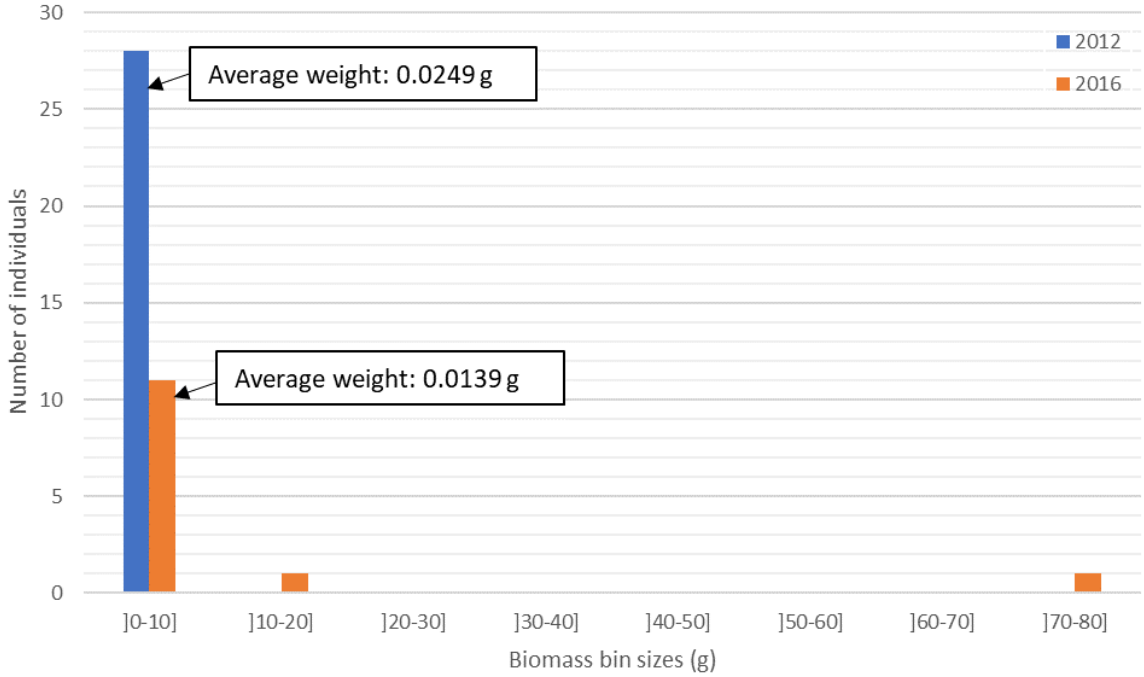

Figure 26. *Arctica islandica* biomass data (g per grab) from the 2012 and 2016 survey at North East of Farnes Deep MCZ.

3.7 Non-indigenous species (NIS)

Two species identified from the grab sample data were listed as invasive in the 'Non-native marine species in British waters: a review and directory' (Eno *et al*. in 1997). The polychaete *Goniadella gracilis* was recorded in grab samples from both 2012 (two stations) and 2016 (three stations) (Figure 27). The soft-shell clam, *Mya arenaria,* was identified in one sample collected during the 2012 survey. There were no non-indigenous taxa observed in the still images.

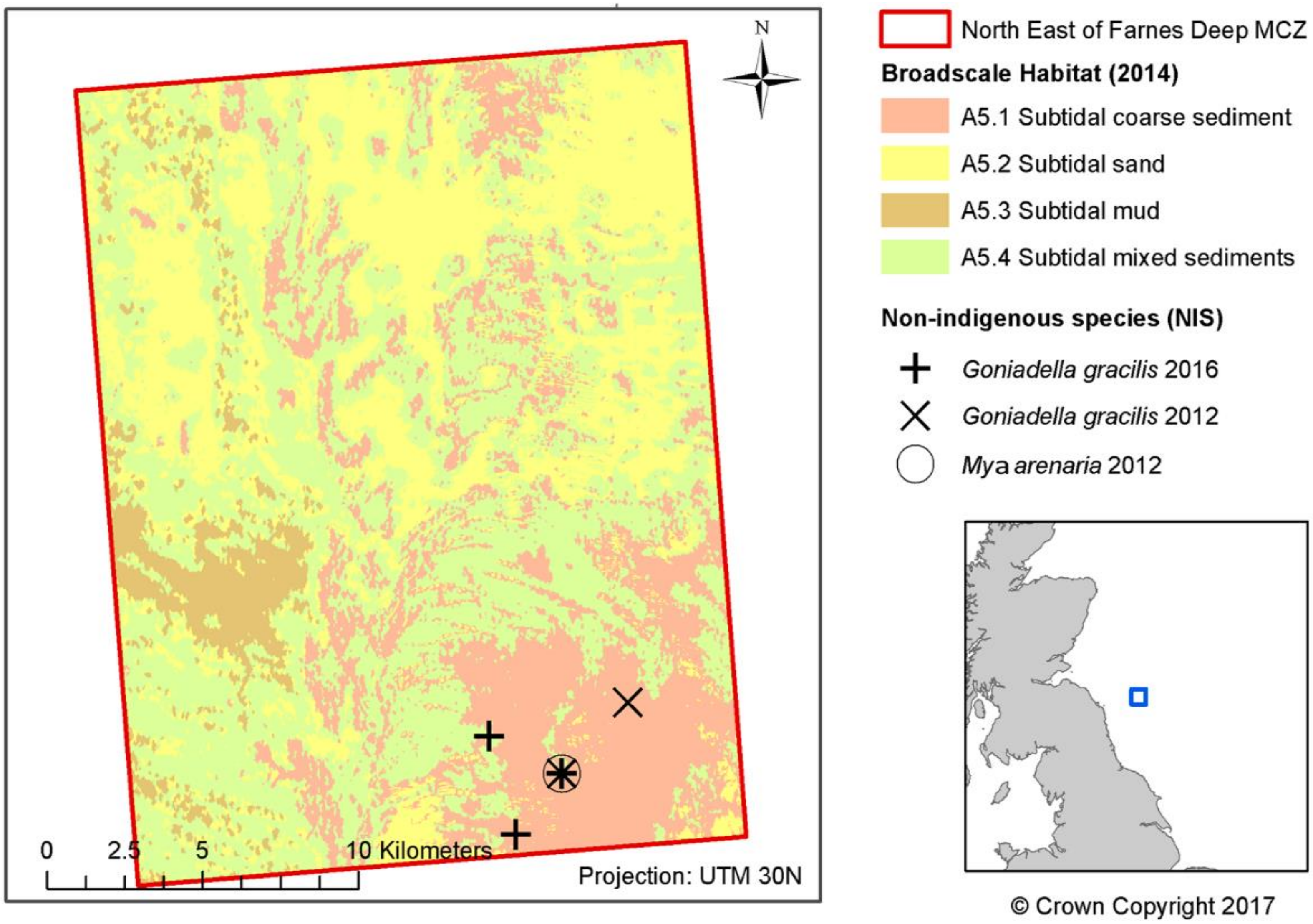

Figure 27. Location of grab samples where non-indigenous species were observed at North East of Farnes Deep MCZ in 2016.

3.8 Marine litter

Observations of marine litter in the seabed imagery data were categorised and recorded according to the protocol provided in Annex 5. Incidences of litter on the seabed were observed in the seabed imagery at two stations (two still images) from the 2016 survey (Figure 28). A plastic bottle (A1) was observed at station NEFD20 in the north east of the site (Figure 29). A small piece of metal sheeting (B8) was observed at station NEFD041 in the far north of the site.

NEFD_CEND1016_NEFD20_STN_296_06	NEFD_CEND1016_NEFD41_STN_302_10
	

Figure 28. Example images of the two items of marine litter identified from the still images collected in 2016 during the survey of North East of Farnes Deep MCZ.

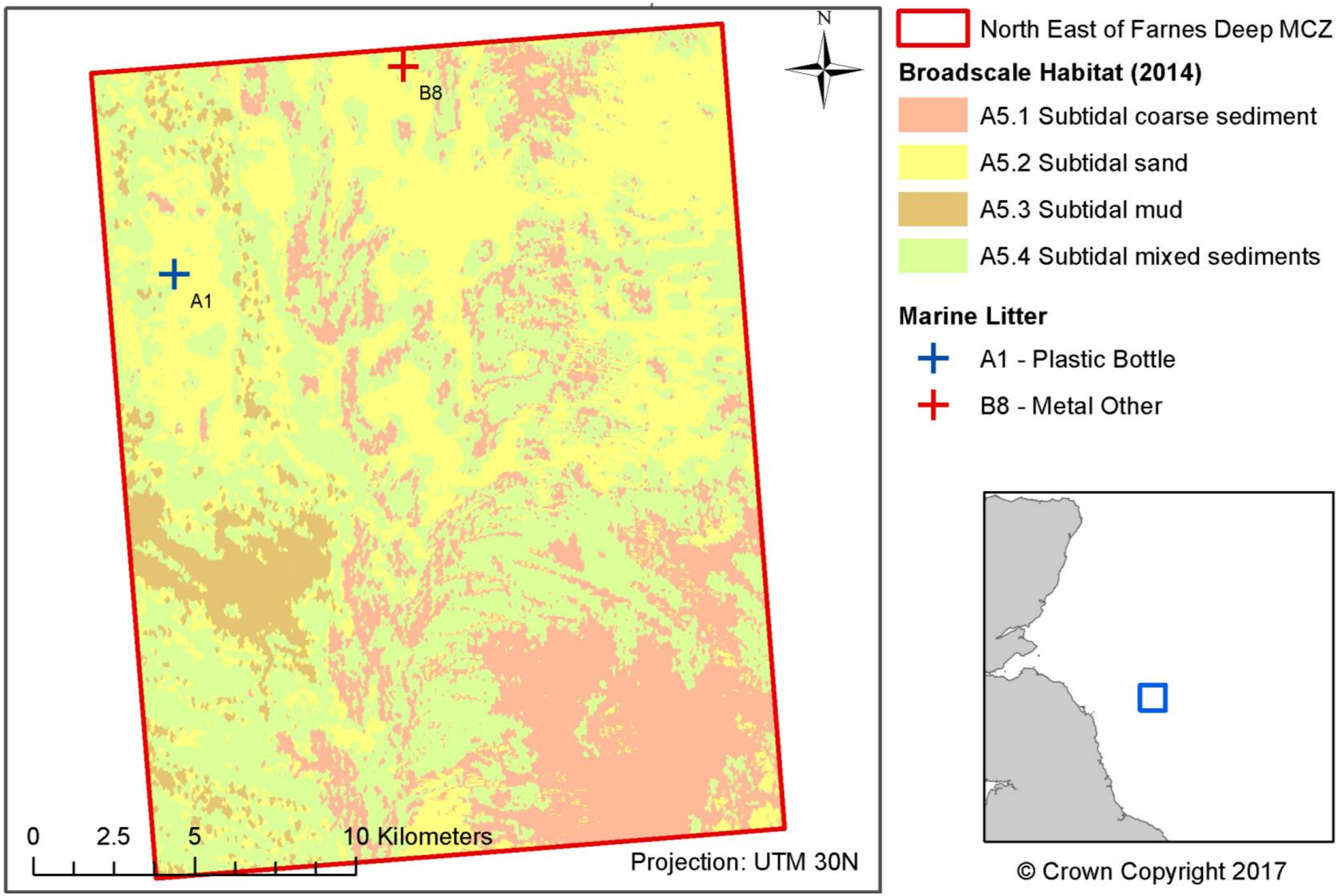

Figure 29. Marine litter observed from 2016 imagery data at North East of Farnes Deep MCZ. Categories for marine litter are derived from OSPAR/ICES/IBTS for North East Atlantic and Baltic.

4 Discussion

4.1 Benthic environment and supporting processes (Objective 1)

The 2016 data confirmed that the seabed within the North East of Farnes Deep MCZ is extremely heterogeneous, as observed from the more limited 2012 data and predicted by the site verification habitat map. All four designated habitat BSH, ‘Subtidal coarse sediment’, ‘Subtidal sand’, ‘Subtidal mud’ and ‘Subtidal mixed sediments’, were recorded across the site, with small discrete patches of ‘Moderate energy circalittoral rock’ as a localised variation of ‘Subtidal coarse sediment’ and ‘Subtidal mixed sediments’. The most commonly encountered BSH was ‘Subtidal sand’, with ‘Subtidal mud’ being the second most common, followed by ‘Subtidal mixed sediments’ and ‘Subtidal coarse sediment’. The overall distribution of BSH was not obviously attributable to the weak tidal regimes, which showed little variation in current strength or direction across the site.

4.2 Designated BSH Features (Objective 2)

4.2.1 Sediment composition

The vast majority of the 2016 grab samples were dominated by sand fractions, with variable proportions of mud and gravel. Two exceptions to this were areas of coarse and mixed sediments in the north east and south east of the site, where several samples were dominated by gravel fractions.

When the full particle size data were superimposed on a BGS-modified Folk triangle, it was clear that the sediments exist along a composition gradient within the site, and the separation of samples into discrete BSH categories (based on PSA data) is arbitrary in places. This is particularly notable for ‘Subtidal sand’ and ‘Subtidal mud’, where samples clustered around the classification boundary for these two BSH. On examination of the triangle, it is also obvious that the sediment distributions within the ‘Subtidal coarse sediment’ and ‘Subtidal mixed sediments’ categories are extremely variable, with large differences in gravel content. These broadscale groupings therefore clearly mask variations in sediment fractions and associated biological communities within the site.

Only one grab sample was acquired per sampling station, therefore the degree of small-scale variation at each station is unknown. Due to the extremely mixed nature of the seabed it may be postulated that localised variation within the vicinity of sampling stations is high. Given that small-scale variation is unquantified and that minor changes in sediment composition can result in a change in BSH membership, such changes should not automatically be interpreted as meaningful (i.e. indicative of a change in condition) in future assessments.

4.2.2 Extent and distribution

The comparison of 2016 sampling data and the site verification habitat map resulted in moderate agreement (62%) between the physical samples and the predicted habitats. It should be noted that this result is unlikely to represent a broadscale change in habitat distribution, but likely illustrates the inherent difficulties in mapping highly heterogeneous and interspersed sedimentary BSH habitats. The areas of disagreement between the 2016 samples and predicted habitat map were generally in areas of predicted ‘Subtidal coarse sediment’ and ‘Subtidal mixed sediments’, particularly where these class predictions were highly interspersed and fragmented, and the edges of the predicted ‘Subtidal mud’ area. These results suggest that large predicted areas of ‘Subtidal sand’ and the centre of the

'Subtidal mud' habitats have been accurately predicted by the habitat map. Large 'objects' on the map appeared more likely to be verified by the 2016 grab samples, however, this was not the case for the large 'Subtidal coarse sediment' area in the south east of the site. Several samples from this area were identified as 'Subtidal mixed sediments', indicating that this area is 'muddier' than predicted by the habitat map.

Given that the sediments exist on a gradient, and cannot be meaningfully differentiated along BSH boundaries, it is unlikely that further acquisition of acoustic or groundtruthing data would allow the extent of the designated BSH to be mapped with confidence. Extent should not therefore be further pursued as an indicator of condition for this site, although continued monitoring of distribution will give an indication of relative extent over time. Replicate sampling at each station would allow an assessment of within station variance of sediment composition, in turn informing the degree of significance any change in BSH membership should be assigned.

4.2.3 Biological communities

As expected, given the results of the PSA, multivariate analysis of the 2016 infaunal data revealed variation in the composition of the infaunal communities. The results of the multivariate analysis support the existence of a main infaunal group, as part of a wider assemblage gradient driven by variation in sediment composition (primarily variation in gravel content). The majority of stations belong to a single cluster group (Group A) derived at 35% similarity, which was found to contain a range of BGS-modified Folk sediment classes, with high variation in gravel content. Stations in this group, despite the notable presence of gravel in some, shared the same broad infaunal assemblage characteristic of muddy sand habitats in the North Sea. Two further groups (Groups B & C) were found to have a similar infaunal composition, being dominated by species typical of muddy sands (*Spiophanes bombyx, Phoronis* sp., *Edwardsia claparedii*, *Ampharete falcata, Galathowenia oculata, Spiophanes kroyeri, Scoloplos armiger* and *Paramphinome jeffreysii*), however, with increased dominance of species associated with coarse sediments (e.g. the pea urchin *Echinocyamus pusillus*).

The remainder of the groups (Groups D, E and F), contained dominant species which attach to, or are-free-living within, hard and coarse sediments (e.g. *Hydroides norvegica*, *Leptochiton asellus*, *E. pusillus* and *Ophiactis balli*). Although differences existed both within and between each of the groups (reflecting the highly heterogeneous sediments), Groups A, B and C can broadly be grouped as 'muddy sand communities' whilst Groups D, E and F can be grouped as 'coarse and mixed sediment communities'.

Considering the assemblages in the context of these two broad and highly variable biological groups is likely to be more ecologically meaningful for future monitoring than BSH classes. Although some differences were found between the infaunal assemblages when compared using BSH as a factor, there was considerable overlap between some classes, providing further evidence that BSH do not equate to discrete categories in terms of infauna at this site.

Unlike the infaunal communities, the epifauna observed from still imagery separated clearly according to BSH, with membership closely aligned to that of the statistically derived cluster groups. This is, perhaps, unsurprising given the difficulty of visually differentiating habitats according to minor differences in sediment composition (particularly mud content). The majority of the still images were therefore classified as one of two relatively discrete categories, 'Subtidal sand' and 'Subtidal coarse sediment' with obvious physical disparities in the amount of gravel and pebbles. It is likely that the BSH categories 'Subtidal sand' and 'Subtidal coarse sediment' contain images which would have been classified as 'Subtidal mud' or 'Subtidal mixed sediments', if a grab sample had been available for the corresponding locations. A comparison between the classification of grab samples and still image samples indicated that there was a tendency for the still image classifications to lean towards the 'Subtidal coarse sediment' when in fact the PSA analysis indicated that the majority of images were collected from areas of 'Subtidal mixed sediments'. As previously discussed, BSH can be differentiated by very minor differences in the ratios of mud and sand at this site, however these minor differences in grain size are likely to have little effect on the epifaunal community.

The epifaunal taxa which dominated the 'Subtidal coarse sediment' BSH were primarily tunicates, Chaetopterid parchment worms and Sabellid polychaetes, bryozoans of the family Flustridae, with large contributions from the Pagurid and Galatheoidid crustaceans as well as Hydrozoa. The epifauna of this BSH type are more diverse and abundant than observed for the BSH 'Subtidal sand', with taxa that require larger particles for attachment.

The epifaunal taxa which showed a strong association with the 'Subtidal sand' BSH are primarily Chaetopterid polychaetes (with a very large similarity contribution of 51.3%) the sea-pen *Pennatula phosphorea* (with a large contributing percentage of 31.4%), sea stars and, to a lesser extent, hermit crabs also contribute. The limited epifaunal diversity within this BSH type is not unexpected, given the predominantly fine nature of the sediment.
Of the epifaunal taxa observed, *P. phosphorea* warrants further consideration as a potential condition indicator within the site, as there is some evidence that this conspicuous taxon may be sensitive to abrasion pressures such as demersal trawling (Murray *et al.* 2016). According to the OSPAR criteria (
Table 3) this metric shows potential in terms of 'Accuracy', 'Simplicity', 'Spatial applicability' and 'Communication'. Further studies would be required to establish whether it would fulfil the 'Sensitivity', 'Specificity', 'Responsiveness', 'Management link' and 'Validity' criteria. This taxon is best recorded using video transect data with a standardised field of view, segmented at regular intervals to allow assessment of localised density along transects.

In general, it should be noted that if the full epifaunal communities are to be monitored in the future, the combination of five still images per transect is unlikely to represent the true occurrence frequency, particularly for rare or sparsely distributed taxa. This low number of images was used in analysis due to the limited numbers of good quality images for each transect. The number of still images acquired per transect should therefore be increased, to ensure a higher number of good quality images for future comparisons.

4.3 Designated FOCI (Objective 3)

4.3.1 Species Features of Conservation Importance (FOCI)

Twenty-three individuals of the species FOCI 'Ocean Quahog' (*Arctica islandica)* were recorded across the site in 2012, and 18 in 2016. It should be noted that the methods used in this survey are not optimal for targeting *A. islandica*, therefore no conclusions should be derived from these results except confirmed presence within the site. Fully quantitative sampling would require an extensive programme of dredging, which is unlikely to align with the conservation objectives for the site. In the absence of reliable abundance data for this species FOCI, future monitoring should therefore focus on the distribution of its supporting habitats. At this point, the habitat preferences of *A. islandica* are not fully understood. The 2016 data suggest a preference for sediments with a lower gravel content, however it is not clear whether this a genuine trend or a sampling artefact (*A. islandica* can burrow relatively deep within the seabed, and coarse samples may be smaller or washed out). Further studies are needed at a broader scale to determine the habitat preferences of *A. islandica* if supporting habitat condition is to be used as an assessment proxy for this species FOCI.

A large majority of the individuals collected within the site are likely to be juvenile, as only two individuals collected in 2016 weighed over 0.01g.

4.4 Temporal comparison (Objective 4)

The inter-year comparison of the 2012 and 2016 repeat stations showed there was some difference in community composition, alongside a change in sediment composition at 11 of the 21 revisited stations, which resulted in a shift in BSH membership over time at these stations. Changes between Entropy sediment group occurred at eight of the 21 stations. However, when these stations were compared in more detail, their particle size frequency distributions were found to be similar, with slight differences in silt/clay content causing a transition to a different Entropy (or BSH) group. This change principally manifests in stations previously classed at ‘Subtidal coarse sediment’ changing to the BSH ‘Subtidal mixed sediments’.

The weak and uniform tidal currents (as modelled) suggest a low energy environment, therefore no significant changes in the sediment regime are expected between monitoring events. The proportions of the finer sediments (sand and mud) are likely to vary over time and may affect the local spatial distribution of the ‘Subtidal coarse sediment’, ‘Subtidal mud’, ‘Subtidal sand’ and ‘Subtidal mixed sediments’ designated BSH features.

On first inspection, the nMDS results (only including data from the 21 comparable stations), indicated that the infaunal assemblage structure appeared to have changed, with no visual overlap between the two years. Further exploration of the data revealed that small changes in the relative abundance of three prominent taxa (*Paramphinome jeffreysii*, *Spiophanes bombyx* and *Ampharete falcata)* were sufficient to ‘split’ the multivariate community structure on the nMDS ordination, alongside changes in the abundance of *Edwardsia claparedii* (likely to be attributable to a taxonomic disparity as opposed to real change). As these two surveys were undertaken at different times of the year (March in 2012 and May in 2016), it is possible that differences in the abundance of *P. jeffreysii*, *S. bombyx* and *A. falcata* may be partly attributed to seasonal variation in their distribution and life cycles.

This direct (revisited stations) approach to temporal comparison is considered indicative only, as a full understanding of within station variability (through replicate infaunal samples) has not yet been achieved.

4.5 Non-indigenous species (NIS) (Objective 5)

Two species were identified in the grab samples which match with those identified as invasive in the ‘Non-native marine species in British waters: a review and directory’ (Eno *et al*. 1997). *Goniadella gracilis* was recorded in both the 2012 and 2016 survey of the site. All of the samples were collected from the south east of the MCZ located in an area predominantly mapped as ‘Subtidal coarse sediment’. However, samples collected during 2016 indicate that the proportion of mud has increased since the 2012 survey, with many of the PSA samples being classified as ‘Subtidal mixed sediments’.

The soft-shell clam, *Mya arenaria*, was recorded in one sample collected during the 2012 survey. This sample was also located in the south west of the site in the predominantly ‘Subtidal coarse sediment’ area.

4.6 Marine litter (Objective 6)

Marine litter was observed from underwater images at two stations, both on sandy substrate. A plastic bottle (MSFD category A1) was observed at a station in the north west of the site, and an apparent piece of metal (B8) was recorded at a station in the extreme north of the site.

5 Recommendations for future monitoring (Objective 7)

The 2016 monitoring survey (in combination with the 2012 data) has allowed a thorough characterisation of the North East of Farnes Deep MCZ and provided evidence for evaluation of the monitoring approaches used.

The following recommendations are made in relation to future monitoring within the site:

- The 2016 data have illustrated that the distribution of BSH is extremely heterogeneous and mosaiced across most of the site. Sediment samples only display moderate agreement with the existing predictive habitat map. The new sediment data should therefore be used in conjunction with the predictive habitat map for any future sampling designs or management decisions.
- Due to the mixed nature of the sediments and the similarity of many samples considered to constitute different BSH, it is likely that monitoring extent as an indicator of condition will be misleading, and that further predictive habitat maps are unlikely to capture the actual extent of the designated BSH at the site level.
- Higher confidence can be placed in map predictions of large 'objects' comprising 'Subtidal sand' and 'Subtidal mud' than mosaiced areas or the large predicted patch of 'Subtidal coarse sediment'. If BSH are to be specifically targeted as strata for future monitoring, positioning stations towards the centre of the larger 'objects' is likely to improve precision within strata. It may be necessary to consider 'Subtidal coarse sediment' and 'Subtidal mixed sediments' as a mosaic habitat.
- It is recommended that the 2012 revisited and 2016 stations are incorporated into future survey designs as 'sentinel' stations, alongside any additional sampling within larger BSH 'objects'. Although randomisation of sampling stations is generally preferable, the extreme variation of the sediments within the site will mean any genuine changes are likely to be masked if sampling stations are moved at each sampling event.
- Replicate sampling within stations will improve our understanding of how variation in sediment fractions and biological communities can be attributed to genuine change through time, or whether observed differences are due to small-scale local variability. This will increase the robustness with which future assessments of condition can be made.
- We recommend that considering infaunal communities as variants within two broad groups; 'muddy sand communities' and 'coarse and mixed sediment communities' would allow more ecologically meaningful assessments than BSH membership, as the communities did not consistently align with the designated BSH. This approach could also be applied to the epifaunal communities. These communities split clearly between 'Subtidal sand' and 'Subtidal coarse sediment', although it is likely that difficulties in discerning mud have resulted in mis-identification of sediments which would be classed as 'Subtidal mud' or 'Subtidal mixed sediments' if grab sampled. This provides further support for two broad 'muddy sand communities' and 'coarse and mixed sediment communities' groups, incorporating both infaunal and epifaunal components of the communities.
- This report has highlighted the probability that the resolution to which taxa are identified is likely to vary between temporal datasets (as seen for Edwardsiidae and *Edwardsia claparedii*). The joint truncation exercise did not entirely mitigate for this issue, as both taxa were recorded in 2016, whilst only Edwardsiidae was recorded in 2012. Analysts should therefore be vigilant and cautious in examining the likely causes of perceived changes in assemblage composition through time.
- Density of the phosphorescent sea-pen, *P. phosphorea*, should be considered for development as a potential indicator of condition within the site. Further studies

should be conducted to establish whether it would fulfil the ‘Sensitivity’, ‘Specificity’, ‘Responsiveness’, ‘Management link’ and ‘Validity’ indicator criteria specified by OSPAR (Table 3). Future surveys could target sea-pens to allow quantitative comparisons of density through time, using video data with a standardised field of view, analysed to a standard video segment length.

- The SACO for the site lists nutrition as a key ‘function’ feature attribute (JNCC 2018c). If this feature attribute was determined to be a priority for future monitoring surveys, the abundance and distribution of key taxa, such as sand eel species (amongst others), could be quantitatively sampled using appropriate methods. Secondary productivity could be monitored across the site, with repeated acquisition of biomass data for both infauna and epifauna. Biomass data for epifauna could be acquired using scientific beam trawls, although the benefits of bottom-contacting methods must be assessed against the potential for damage to the designated features of the site.
- Climate regulation is also listed as a key ‘function’ feature attribute. Future surveys could assess the role of the sedimentary habitats in providing a long-term sink for carbon. If this is a priority, total organic carbon (TOC) should be measured from grab samples. This data would also allow more accurate modelling of patterns in biological communities.
- Marine litter was recorded from seabed imagery data only. If required, further evidence on this MSFD Descriptor could be derived by analysing sediment sub-samples for microplastics.
- If possible, future surveys should be conducted at the same time of year as the 2016 survey (May), to avoid seasonal fluctuations in faunal distribution and abundance.
- It is unlikely that a fully quantitative sample of *Arctica islandica* will be achievable or advisable at the site level, given its slow growth rate and longevity, its apparently sparse distribution and the destructive methods required. Further studies are therefore required to improve our understanding of *A. islandica* habitat preferences, to enable monitoring of the condition of its supporting habitats.

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Annex 1. Revisited station codes

2016 station code	2012 station code
NEFD23	RU_S_28
NEFD04	RU_C_07
NEFD11	RU_C_20
NEFD03	RU_C_06
NEFD17	RU_S_11
NEFD05	RU_C_12
NEFD08	RU_C_16
NEFD12	RU_C_21
NEFD22	RU_S_26
NEFD07	RU_C_15
NEFD09	RU_C_18
NEFD13	RU_S_01
NEFD01	RU_C_01
NEFD16	RU_S_09
NEFD18	RU_S_13
NEFD06	RU_C_13
NEFD20	RU_S_21
NEFD15	RU_S_07
NEFD78	RU_S_18
NEFD19	RU_S_19
NEFD80	RU_S_08

Annex 2. Infauna data truncation protocol

Raw taxon abundance and biomass matrices can often contain entries that include the same taxa recorded differently, erroneously or differentiated according to unorthodox, subjective criteria. Therefore, ahead of analysis, data should be checked and truncated to ensure that each row represents a legitimate taxon and they are consistently recorded within the dataset. An artificially inflated taxon list (i.e. one that has not had spurious entries removed) risks distorting the interpretation of pattern contained within the sampled assemblage.

It is often the case that some taxa have to be merged to a level in the taxonomic hierarchy that is higher than the level at which they were identified. In such situations, a compromise must be reached between the level of information lost by discarding recorded detail on a taxon's identity and the potential for error in analyses, results and interpretation if that detail is retained.

Details of the data preparation and truncation protocols applied to the infaunal datasets acquired at North East of Farnes Deep MCZ ahead of the analyses reported here are provided below:

- taxa are often assigned as 'juveniles' during the identification stage with little evidence for their actual reproductive natural history (with the exception of some well-studied molluscs and commercial species). Many truncation methods involve the removal of all 'juveniles'. However, a decision must be made on whether removal of all juveniles from the dataset is appropriate or whether they should be combined with the adults of the same species where present. For the infaunal data collected at the North East of Farnes Deep MCZ: where a species level identification was labelled 'juvenile', the record was combined with the associated species level identification, when present, or the 'juvenile' label removed where no adults of the same species had been recorded;
- records of meiofauna were removed;
- records of eggs and fragments of individuals were removed;
- records of algae, fish and litter were removed;
- unique records at a Kingdom, Phylum or Order taxonomic level were removed (Animalia, Bivalvia, Sessilia);
- where there are records of one named species together with records of members of the same genus (but the latter not identified to species level) the entries are merged, and the resulting entry retains only the name of the genus (e.g. Table 12).

Table 12. Example of truncation: entries are merged to the genus name when the identification level was different between years.

Accepted taxon			Assigned taxon
#	**2012**	**2016**	
1	*Antalis*	*Antalis entalis*	*Antalis sp.*
2	Campanulariidae	*Campanularia hincksii*	Campanulariidae
3	*Chone*	*Chone fauveli*	*Chone sp.*
4	*Cirratulus*	*Cirratulus cirratus*	*Cirratulus sp.*
5	*Clytia*	*Clytia gracilis*	*Clytia sp.*
		Clytia hemisphaerica	—
6	*Crisia*	—	Crisiidae
	Crisiidae		
7	*Euchone*	*Euchone rubrocincta*	*Euchone sp.*
8	Haleciidae	*Halecium*	Haleciidae
9	*Jasmineira*	*Jasmineira caudata*	*Jasmineira sp.*
		Jasmineira elegans	
10	*Leptosynapta*	*Leptosynapta bergensis*	*Leptosynapta sp.*
		Leptosynapta decaria	
11	Onchidorididae	*Onchidoris muricata*	Onchidorididae
12	*Owenia fusiformis*	*Owenia*	Oweniidae
13	Oweniidae		
14	*Phascolion (Phascolion) strombus*	*Phascolion (Phascolion) strombus strombus*	*Phascolion (Phascolion) strombus*
15	*Philine aperta*	*Philine*	*Philine sp.*
16	*Porella compressa*	*Porella*	*Porella sp.*
	Porella concinna		
	Porella laevis		
17	*Streblosoma bairdi*	*Streblosoma*	*Streblosoma sp.*
18	*Terebellides stroemii*	*Terebellides*	*Terebellides sp.*

Annex 3. Epifauna data truncation protocol applied to seabed imagery data

Still image data were collated from surveys carried out during 2012 and 2016. On examination of the taxonomic notation used in analysing the stills acquired during the different surveys, the datasets exhibited differences between the taxonomic detail recorded, with more taxa assigned to lower levels (genera and species) in the more recently acquired data. In addition, the results of image analysis differed in relation to the level of taxonomic detail assigned to different still images.

Initially, all assigned taxon names were collated with accompanying counts of occurrences in each data set. All taxon names were linked to an entry in an aggregation matrix forming a truncation matrix that was used as a basis for decisions. Table 13 shows an extract of the truncation matrix used to reassign taxon labels. Uncertain and vague taxa (such as 'Animalia crust') and all fish were removed. Other taxa were combined to the highest common taxonomic level with some exceptions detailed below.

Table 13. Extract from the epifauna truncation matrix. Levels 2–6 represent taxonomic level from genera to phyla in the aggregation matrix. Recorded taxon contains each unique entry from combined abundance matrices. Assigned taxon shows the taxon name after truncation.

Level 6	Level 5	Level 4	Level 3	Level 2	Recorded Taxon	Assigned Taxon
Arthropoda	Malacostraca	Decapoda	Munididae	Munida	*Munida rugosa*	*Munida rugosa*
Arthropoda	Malacostraca	Decapoda	Paguridae	Pagurus	*Pagurus prideaux*	Paguridae
Arthropoda	Malacostraca	Decapoda	Paguridae	Paguridae	Paguridae	Paguridae
Arthropoda	Malacostraca	Decapoda	Polybiidae	Liocarcinus	*Liocarcinus depurator*	*Liocarcinus depurator*
Arthropoda	Malacostraca	Decapoda	Pandalidae	Pandalidae	Pandalidae	Caridea
Arthropoda	Malacostraca	Decapoda	Caridea	Caridea	Caridea	Caridea
Arthropoda	Malacostraca	Decapoda	Brachyura	Brachyura	Brachyura	Decapoda
Arthropoda	Malacostraca	Decapoda	Decapoda	Decapoda	Decapoda	Decapoda
Arthropoda	Malacostraca	Decapoda	Galatheoidea	Galatheoidea	Galatheoidea	Decapoda
Arthropoda	Malacostraca	Decapoda	Majoidea	Majoidea	Majoidea	Decapoda
Arthropoda	Crustacea	Crustacea	Crustacea	Crustacea	Crustacea	Crustacea
Bryozoa	Gymnolaemata	Cheilostomatida	Flustridae	Flustra	*Flustra foliacea*	Flustridae
Bryozoa	Gymnolaemata	Cheilostomatida	Flustridae	Flustridae	Flustridae	Flustridae
Bryozoa	Gymnolaemata	Cheilostomatida	Phidoloporidae	Reteporella	Reteporella	Reteporella
Bryozoa	Gymnolaemata	Cheilostomatida	Celleporoidea	Celleporoidea	Celleporoidea	Celleporoidea
Bryozoa	Gymnolaemata	Ctenostomatida	Alcyonidiidae	*Alcyonidium*	*Alcyonidium*	*Alcyonidium*
Bryozoa	Bryozoa	Bryozoa	Bryozoa	Bryozoa	Bryozoa	Bryozoa
Chordata	Actinopteri	Actinopteri	Actinopteri	Actinopteri	Actinopteri	Remove

The 2012 dataset comprised records of taxa at a less resolute level of identification compared to the 2016 data. In most cases, taxa were truncated to the highest common taxonomic level. Where there was a mixture of taxonomic levels, with several observations given both at a group level and for individual taxa of that group, the more detailed taxonomic groups were kept separate to maintain as much taxonomic detail as possible. This occurred with the taxa within the group Decapoda where the harbour crab, *Liocarcinus depurator*, was kept separate whilst several taxa were truncated to the order Decapoda. Although Bryozoa was the highest common taxonomic level for species of bryozoan, and a category within both the 2012 and 2016 data, most species identified to genus or species level in the 2016 data were easily identifiable and so were not truncated. All other taxa were grouped to the highest common taxonomic level identified between the two lots.

Annex 4. Non-indigenous species (NIS)

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		

Additional taxa listed as non-indigenous species in the JNCC 'Non-native marine species in British waters: a review and directory' report by Eno *et al*. (1997) which have not been selected for assessment of Good Environmental Status in GB waters under MSFD Descriptor 2.

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	
Rhithropanopeus harrissii	

Potamopyrgus antipodarum	
Tiostrea lutaria	*Tiostrea chilensis*
Mercenaria mercenaria	
Petricola pholadiformis	
Mya arenaria	

Annex 5. Marine litter

Categories and sub-categories of litter items for Sea-Floor from the OSPAR/ICES/IBTS for North East Atlantic and Baltic. Guidance on Monitoring of Marine Litter in European Seas, a guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive, MSFD Technical Subgroup on Marine Litter, 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*5cm = 25cm²

B: ≤ 10*10cm = 100cm²

C: ≤ 20*20cm = 400cm²

D: ≤ 50*50cm = 2500cm²

E: ≤ 100*100cm = 10000cm²

F: ≥ 100*100cm = 10000cm²

Annex 6. Acknowledgement

North East of Farnes Deep Marine Conservation Zone (MCZ) Monitoring Report 2016

MPA Monitoring Programme

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Association of IFCA
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Marine Management Organisation
NATURAL ENGLAND

Marine Protected Areas Survey Coordination & Evidence Delivery Group

This work was delivered by Cefas and JNCC on behalf of the Marine Protected Areas Survey Coordination & Evidence Delivery Group (MPAG) and sponsored by Defra. MPAG was established in November 2012 and continued until March 2020. MPAG, was originally established to deliver evidence for Marine Conservation Zones (MCZs) recommended for designation. In 2016, the programme of work was refocused towards delivering the evolving requirements for Marine Protected Area (MPA) data and evidence gathering to inform the assessment of the condition of designated sites and features by SNCBs, in order to inform Secretary of State reporting to Parliament. MPAG was primarily comprised of members from Defra and its delivery bodies which have MPA evidence and monitoring budgets and/or survey capability. Members included representatives from Defra, JNCC, Natural England, Cefas, the Environment Agency, the Inshore Fisheries Conservation Authorities (IFCAs) and the Marine Management Organisation (MMO)).

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