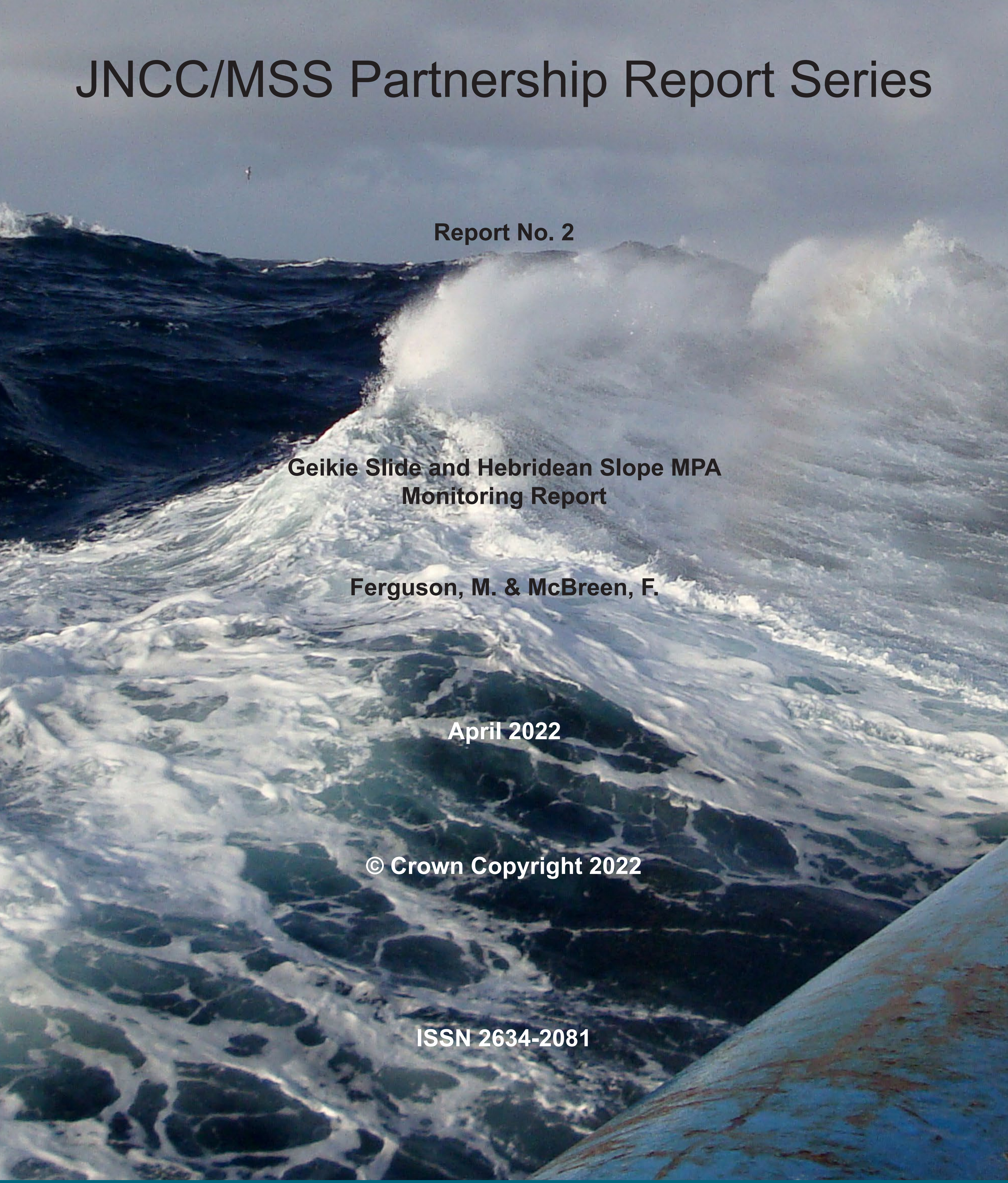

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Geikie Slide and Hebridean Slope MPA Monitoring Report

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Executive Summary

The Geikie Slide and Hebridean Slope Marine Protected Area (MPA) is located to the north-west of Scotland and follows the descent of the seabed from the Hebridean continental shelf at a depth of 200 m into the deep-sea of the Rockall Trough. The protected features of the site investigated in this report were offshore deep-sea muds, burrowed mud and offshore subtidal sands and gravels. In the summer of 2016, the Joint Nature Conservation Committee (JNCC) and Marine Scotland Science (MSS) completed a survey to the Geikie Slide and Hebridean Slope MPA to collect sediment samples (box corer) and seabed images (drop camera and chariot) to characterise the site and provide the first point in a monitoring time-series.

The aim of this report is to explore and describe the protected habitat features within the Geikie Slide and Hebridean Slope MPA and test a number of hypotheses using the evidence collected during this survey. The specific objectives are described in Table 1, alongside a summary of the outcomes.

Table ES1: Objectives and outcomes of the 2016 Geikie Slide and Hebridean Slope MPA survey.

Objectives	Outcomes
Describe the **extent, distribution, structure and function** of offshore deep-sea muds, burrowed mud, and offshore subtidal sands and gravels within each box surveyed at GSH	Mud is much more widespread within the site than previously predicted but co-exists under a widespread layer of coarser sediments, primarily sands. The infauna present within the mud are structured along a significant depth gradient at the site, whilst the epifauna show high variability being structured only by the presence/absence of taxa.
Compare physical and biological characteristics of Boxes D (inside the MPA) and F (outside the MPA), to determine whether they are suitable control and impact sites for a future before after control impact (BACI) study	Survey boxes outside and inside the MPA boundary were compared using several metrics: distribution of PMFs, composition, structure and diversity of both epifaunal and infaunal communities. While some metrics vary between boxes, overall, the boxes are suitable for the 'Before' and 'Control' sites for a BACI type study at GSH.
Evaluate the accuracy of the Hughes *et al.* (2014) biological community zones model within GSH	The Hughes *et al.* (2014) model was found to be accurate in some cases, such as for the upper slope zone, but inaccurate when describing the distribution of xenophyophores and burrowing megafauna in the deeper areas of the site.
Describe the character and distribution of any Priority Marine Features (PMFs) observed which are not designated features of the site	No undesignated benthic PMFs were detected during the analysis of data from GSH. Some mobile (e.g. *Lophius piscatorius*) and limited mobility benthic (e.g. *Pachycerianthus sp.*, *Nephrops norvegicus, Geodia nodastrella*) species of interest were present, but these observations do not constitute nationally or internationally significant populations, especially given their wide distribution across the NE Atlantic.
Present any evidence of human impacts.	Several instances of litter were identified within the site, along with one example of potential mobile fishing gear activity (i.e. trawl marks). No non-indigenous species were identified.

The new evidence and the analysis detailed within this report has updated our understanding on the protected habitat features of the Geikie Slide and Hebridean Slope MPA. In particular, offshore deep-sea muds cover a much greater extent than previously predicted and are distributed from shallow waters down the continental slope and into deeper water. However, the presence of sands and coarse sediments, associated with the offshore subtidal sands and gravels PMF, throughout the site suggests a complex mosaic of coarser material overlying extensive areas of mud.

Further information on the observations made during survey and subsequent analysis of the data for each of the protected habitat features of the site are provided below:

Offshore deep-sea muds

For offshore deep-sea muds, analysis of the box corer data suggests a much greater **extent and distribution** of offshore deep-sea mud within the site than previous data and models. The data show that mud is present throughout the site. However, this mud is not necessarily present in isolation from other sediment types and in some locations may exist solely in deep sediment horizons beyond which the majority of fauna are found.

We have also improved our understanding of the **biological structure** of the faunal communities of the offshore deep-sea muds in GSH. These clearly show that depth is the primary driver of variation. On the continental slope and at the base of the slope numerous deep-sea specific taxa were identified. The overall assemblage is dominated by polychaetes, especially *Glycera spp.*, deep-sea specific taxa including polychaetes (e.g. *Eusthenelais hibernica, Paranaitis* cf. *uschakovi, Linopherus hemuli, Samythella elongata, Pseudexogone dineti*), Syllidae (e.g. *Parexogone longicirris* and *Exogone sorbei*), and Paraonidae (e.g. *Levinsenia flava, L. kantaurensis* and *Paradoneis mikeli*) were found. Crustacea were also notably diverse within the site; several crustaceans, such as *Styloptocuma gracillimum, Platysympus typicus* and *Makrokylindrus josephinae,* recorded alongside isopods typical of deeper water and the deep-water decapods *Dorhynchus thomsoni* and *Cymonomus granulatus*. In addition, several deep-sea ophiuroids (*Ophiacantha abyssicola, Ophiocten abyssicolum and Dictenophiura carnea*), deep-sea Nuculanidae and deep-sea gastropods *Amphissa acutecostata* were also present.

Burrowed mud

For burrowed mud, the particle size data suggests a much greater **extent and distribution** of this feature within the site than previous data and models. The widespread distribution of mud and presence of burrows means that this PMF is widely distributed throughout the deeper areas of the site, although it should be noted that the absolute number of burrows present at GSH is low throughout.

We have also improved our understanding of the **biological structure** of the faunal communities of burrowed mud in GSH. Many characteristic fauna of the burrowed mud PMF were not present in the sediment samples. Only two individuals of *Callianassa subterranea* were recorded and no other mud shrimps (e.g. *Calocaris macandreae*) or burrowing amphipods (e.g. *Maera loveni*) were recorded. Additionally, no echiurans (e.g. *Maxmuelleria lankesteri*) were recorded. This could be because the burrowed mud PMF in the deep-sea is poorly described. Seabed imagery showed abundant burrow openings, of which some were identifiable as *Nephrops norvegicus* burrows. No seapens were detected from the seabed imagery. An increase in the abundance of burrows with depth was observed, suggesting improved conditions for burrowing megafauna with depth.

Offshore subtidal sands and gravels

The sediment classifications from imagery (both video and stills) (Figure 11) point to wider distribution of the feature in the surface sediments in the deepest parts of the site. The disparity between the substrate classifications from box corer samples and imagery data indicate that the use of a single habitat description (mud, sand, coarse or mixed sediment) is a poor descriptor of the layering evident from field notes and underestimates the prevalence of sands and gravels across the site.

We have also improved our understanding of the **physical structure** of offshore subtidal sands and gravels within GSH, where these are primarily a veneer over an underlying layer of mud. We have also improved our understanding of the **biological structure w**here it was possible to identify a community level biotope, with the following biotopes observed:

- 'Urchin dominated community on Atlantic upper bathyal coarse sediment' (M.AtUB.Co.UrcCom) biotope, where *Cidaris cidaris* were recorded in high numbers, often alongside holothurians (*Parastichopus tremulus*).
- 'Xenophyophore dominated community on Atlantic lower bathyal coarse sediment' (M.AtLB.Co.XenCom).
- 'Xenophyophore dominated community on Atlantic lower bathyal coarse sand' (M.AtLB.Sa[XenCom])
- a proposed biotope of M.AtUB.Co[Ditrupa] due to the presence of considerable numbers of *Ditrupa arietina* shells on coarse sediment.
- 'Surface dwelling ophiuroid community on Atlantic lower bathyal mixed sediment' (M.AtLB.Mx.SurOph).

The report describes a number of operational, sampling design and analysis/interpretation recommendations for how to approach the future monitoring of GSH, and the wider MPA network (Table 2).

Table ES2: Recommendations for future monitoring of GSH and the wider MPA network.

Recommendations for future monitoring of GSH	Recommendations for future monitoring of the wider MPA network
• A 0.5mm sieve is preferable to a 0.25mm sieve, with both showing the same overall community patterns. • Collection of Chariot imagery has limited additional value at GSH • A narrower sediment horizon for PSA and infaunal samples will improve comparability to other studies in the area. • The complex nature of veneered sediment must be interpreted with care, especially when considering the disparity in results between imagery and physical samples.	• When using box cores, it is sensible to either limit the sediment processed or increase sieving capacity. • Mechanical damage to infauna has hindered species identification, as such protocols may need to be modified. • Collection of added value sediment characteristics may improve understanding of the physical structure and function of PMFs. • The use of a boxed survey design has been shown to be an effective way to sample a large MPA with a known pre-existing environmental gradient (depth) with limited pre-existing data. • The Hughes *et al.* (2014) biological community zones model does not need further ground truthing to support the offshore MPA monitoring programme • The deep-sea section of the Marine Habitat Classification of Britain and Ireland should be further developed, especially to better represent infaunal biotopes.

Recommendations for future monitoring of GSH	Recommendations for future monitoring of the wider MPA network
	• Development of a deep-sea specific non-indigenous species list would assist scientists in evaluating the current and future spread of these species

Contents

1 Introduction

The Geikie Slide and Hebridean Slope Nature Conservation Marine Protected Area (MPA), hereafter referred to as 'GSH', is part of a network of nationally designated sites designed to meet the requirements of the Marine and Coastal Access Act 2009. These sites also contribute to an ecologically coherent network of MPAs across the North-east Atlantic, as agreed under the Oslo Paris (OSPAR) Convention, and other international commitments to which the UK is signatory.

Under the Marine and Coastal Access Act 2009, Scottish Ministers have devolved responsibility to designate MPAs within Scottish Waters and must assess whether those MPAs are meeting their conservation objectives. Marine Scotland Science, in partnership with Scottish Natural Heritage (SNH) and the Joint Nature Conservation Committee (JNCC), has developed a Scottish Marine Protected Area (MPA) monitoring strategy[1]. The strategy aims to provide direction for monitoring, assessment and reporting on the MPA network and guidance on standardisation of monitoring objectives, sampling design, and methodologies. JNCC is the statutory nature conservation body (SNCB) responsible for nature conservation in the UK offshore environment (between 12 and 200 nautical miles from the mean low-water mark of the shore) and conducts a monitoring programme within this area. The aim of this monitoring programme is to collect the necessary information from the Scottish MPA network to underpin assessment and reporting obligations. Where possible, this monitoring should 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 initial monitoring report explores data acquired from the first dedicated monitoring survey of GSH. The data will inform the development of an effective site and feature-specific monitoring approach for the site. The specific aims of the report are detailed in Section 1.4.4.

1.1 Site overview

GSH lies to the west of the Hebrides and mainland Scotland, with the closest land approximately 27 km away at St. Kilda (Figure 1). This offshore site protects a 2,215 km^2 area of seabed descending from less than 200 m in the southeast of the site to 1,700 m in the west over a distance of approximately 74 km. The site is characterised by a range of habitats predicted to vary with increasing depth (Figure 1 and Figure 2). The distribution of sand and gravel habitats on the continental shelf is related to depth across the site, changing to mud as depth increases. The mud is characterised by a range of burrowing fauna and a diverse range of other taxa including sea urchins, sea stars, xenophyophores and polychaetes as well as commercially important crustacean and fish species.

The Hebridean slope is thought to have functional significance for the health and biodiversity of Scottish seas through increased water column mixing and subsequently increased levels of biological productivity. Large-scale submarine landslides such as the Geikie Slide are also considered characteristic geodiversity features along the Scottish continental slope.

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[1] https://www2.gov.scot/Resource/0052/00521312.pdf

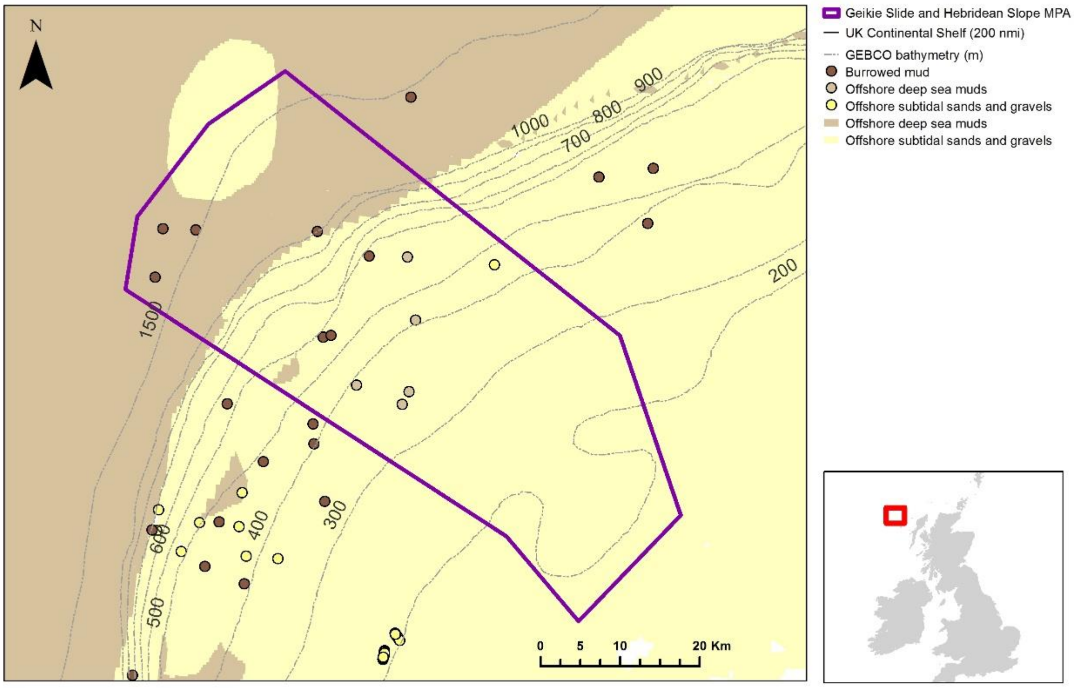

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Figure 1: Distribution of the Priority Marine Features (PMFs): Burrowed Mud, Offshore deep sea muds and Offshore subtidal sands and gravels from the Geodatabase of Marine features adjacent to Scotland (GeMS) (version 5).

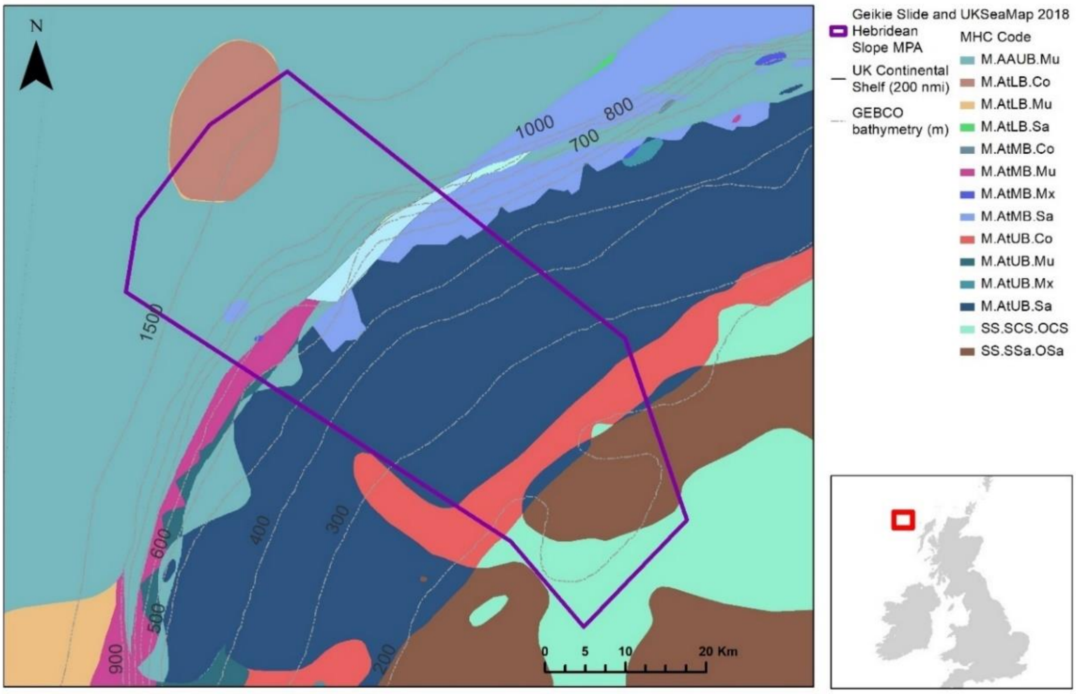

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Figure 2: Habitats of classified by the Marine Habitat Classification of Britain & Ireland v15.03) the Geikie Slide and Hebridean Slope MPA. Habitat map data is given in Marine Habitat Classification of Britain and Ireland (MHC) codes derived from UKSeaMap (2018 v2).

At the time of the survey, proposals for the management of demersal fisheries within the site had been published by Marine Scotland and were being developed under the Common Fisheries Policy (CFP) Joint Recommendations Process[2].

1.2 Feature description

The site was designated to protect five features: offshore deep-sea muds, burrowed mud, offshore subtidal sands and gravels, the continental slope and slide deposit and slide scars representative of the Geikie Slide Key Geodiversity Area. Assessment of the latter two are beyond the scope of this report as they are large-scale geomorphological features outside the remit of the current marine biodiversity monitoring programme. Summaries of the monitored features are provided below (adapted from Tyler-Walters *et al.* 2016).

1.2.1 Offshore deep-sea muds

One of the most widespread and common habitats in the Scottish offshore environment between depths of 200 and 2500 m, offshore deep-sea muds support a wealth of biological diversity. Characterising epifauna include sea cucumbers, brittlestars, sea urchins, sea spiders and fish as well as a range of characterising infauna such as molluscs, crustaceans and worms. Bathymetry, current velocity, bottom water-mass distribution and particle size of the mud (clay, silty or sandy) all have a significant influence on the distribution and composition of the seabed communities present. This habitat also includes the Atlantic and Arctic bathyal and abyssal sediments which occur off the continental slope in Scotland (Figure 2).

1.2.2 Burrowed mud

This feature is characterised by areas of fine sediments from shallow water (10 m) to the deep sea that are home to a range of burrowing fauna, including *Nephrops norvegicus*, mud shrimps and burrowing crabs. The burrowing action of these taxa makes burrows and mounds a prominent feature of this habitat. In some areas, burrowed mud may support conspicuous populations of seapens, typically *Virgularia mirabilis* and *Pennatula phosphorea*, although in deeper waters *Kophobelemnon stelliferum* and *Umbellula encrinus* may be recorded. This habitat can also support populations of cerianthid anemones, such as *Pachycerianthus multiplicatus* and the echiuran *Maxmuelleria lankesteri*. Given that Scottish waters support an estimated 95% of British records of this feature, their contribution to the wider UK and northwest Atlantic is notable.

1.2.3 Offshore subtidal sands and gravels

Sand and gravel sediments are the most common subtidal habitat around the coast of the British Isles. Offshore sand and gravel sediments are widespread in Scottish offshore waters and occur in depths of 200 to 3000 m. This feature is also noted for diverse infaunal communities. Depending on the exact composition of the sediments (proportions of gravel, sand and finer materials) and structuring factors such as current and wave regime and depth of the sediment over bedrock, the infaunal community will vary and may support fauna such as tube dwelling polychaetes, burrowing brittlestars, bivalves, sea urchins or amphipods. Alongside infauna, a range of mobile epifauna including flatfish, starfish, crabs and hermit crabs, may be present. This feature also supports a number of important commercial fisheries such as scallops, flatfish, sandeels and roundfish.

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[2] https://www.webarchive.org.uk/wayback/archive/3000/https://www.gov.scot/Resource/0050/00505826.pdf

1.3 Existing data

While this survey is the first dedicated monitoring survey of GSH, some previous data are available (Figure 3). These data include sources from the Geodatabase for Marine Habitats and Species in Scotland (GeMS)[3], the British Geological Survey (BGS) and data products from a JNCC commissioned analysis of existing survey data (Allen *et al.* 2014; Axelsson *et al.* 2014). These records have been derived from a range of sources including historic trawl records, underwater TV surveys, gravity cores and Shipek grabs. Additionally, limited multibeam bathymetry and backscatter products are available from the RRS James Cook cruise 136 Deep Links survey (Howell *et al.* 2016).

Hughes *et al.* (2014) conducted biotope analysis to characterise the biological diversity of the wider Hebridean slope region based on archived stills data from 1988-1998 (Figure 4). The findings predict five distinct biological zones with associated communities that change with depth on the slope, and GSH is predicted to contain examples of each:

- **Outer shelf and shelf break zone (135 – 227 m)** – characterised by coarse sediments ranging from strongly rippled sand and gravel plains to dense fields of cobbles and small boulders. Visible fauna is sparse in this zone and is dominated by echinoderms such as the pencil urchin *Cidaris cidaris* and asteroids.

- **Upper slope zone (279 – 470 m)** – generally characterised by coarser sediments with sand and gravel patches and predominantly includes echinoderms as visible fauna.

- ***Ophiocten gracilis* zone (600 – 1020 m)** – a biological zone dominated by large numbers of the small brittlestar *Ophiocten gracilis* on fine sandy, muddy sand or sandy mud, with some areas of gravel or cobbles.

- **Xenophyophore zone (1088 - 1180 m)** – a biological zone characterised by the xenophyophore *Syringammina fragilissima* in rippled muddy sand or sandy mud.

- **Decapod burrowing zone (1293 – 1595 m)** – a biological zone characterised by the burrows of large decapods, such as *Munida tenuimana* in fine muds.

Whilst the analysis was carried out on a wider geographic scale than GSH (i.e. limited information from within GSH was available to inform the analysis), the data were used to inform survey planning, and the accuracy of predicted habitat zones against data collected from this survey will be addressed within this report (Section 3.5).

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[3] GeMS Iteration 21.

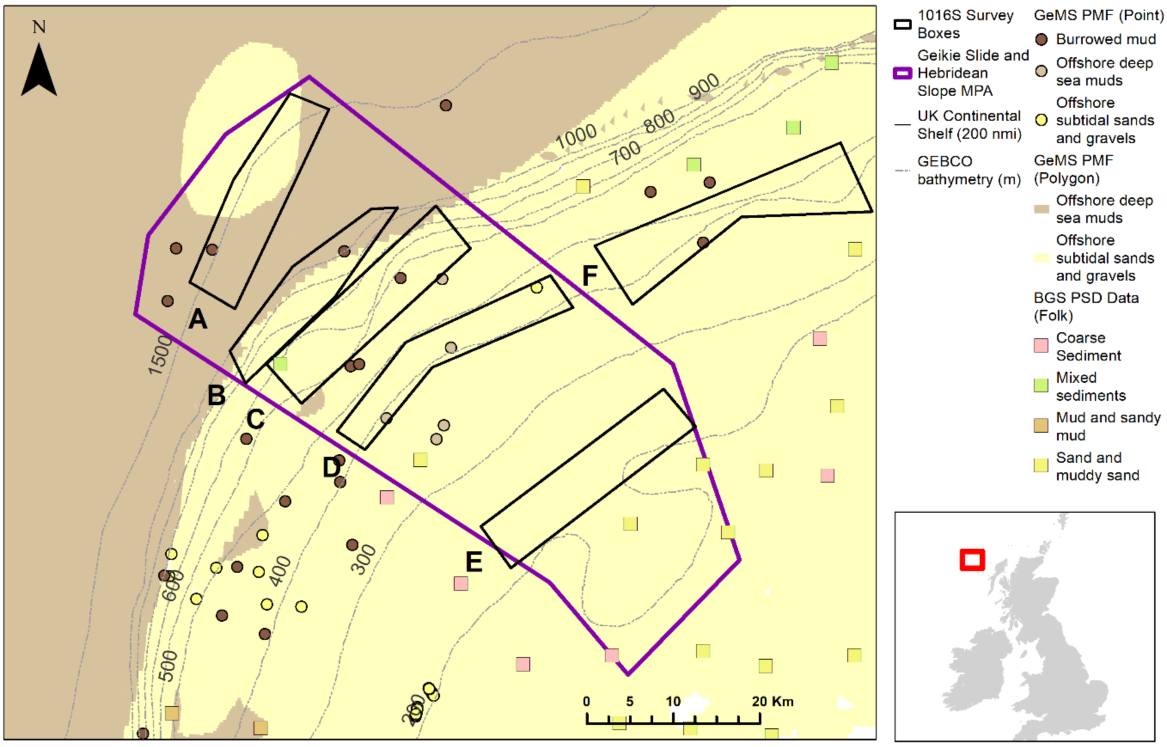

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Figure 3: Existing survey data available prior to the 1016S survey.

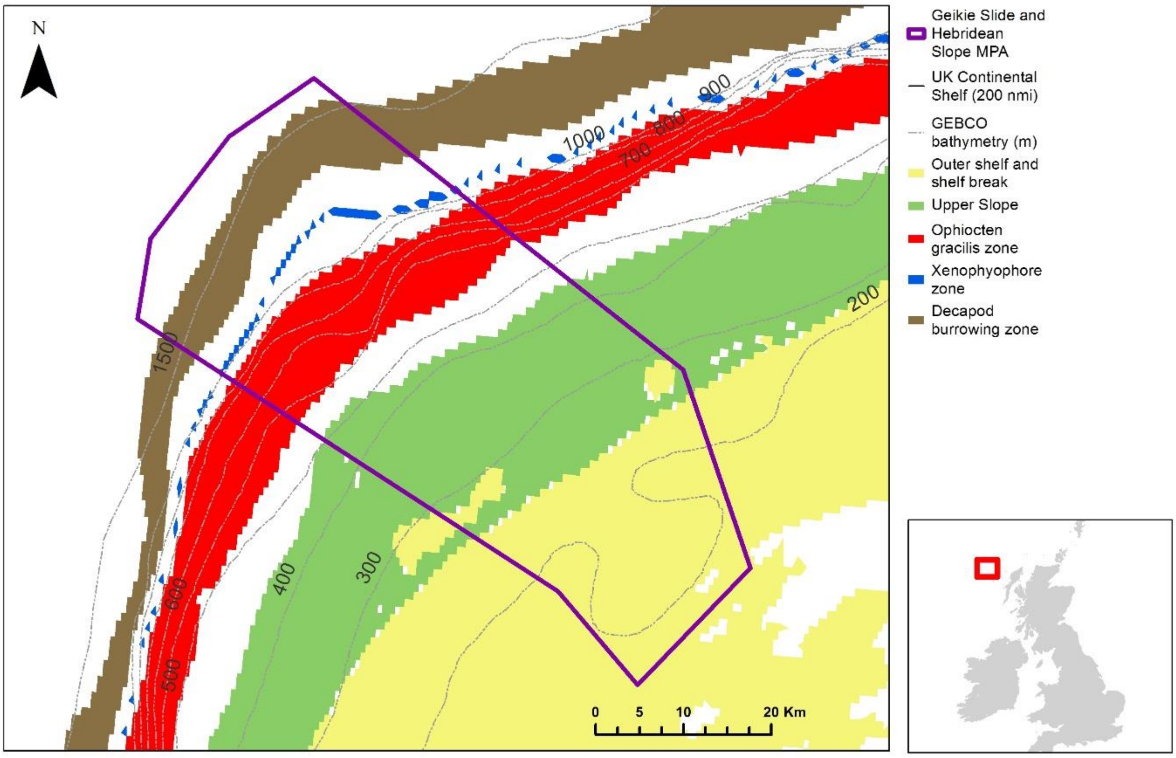

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Figure 4: Location of biological community zones as proposed by the Hughes *et al.* (2014) model.

1.4 Aims and objectives

1.4.1 High-level conservation objectives

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

As detailed in the Geikie Slide and Hebridean Slope Marine Protected Area Order 2014[4], the conservation objectives for the site are that the protected 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.

For offshore deep-sea muds, burrowed mud and offshore subtidal sands and gravels this means that:

- Extent is stable or increasing (where the feature does not already occupy the full extent of the site); and
- Structure, functions, quality, and the composition of characteristic biological communities (which includes a reference to the diversity and abundance of marine fauna forming part of or inhabiting each habitat) are such as to ensure that they remain in a condition which is healthy and not deteriorating.

1.4.2 Feature attributes and supporting processes

This report will present evidence on a number of feature attributes as defined in the supplementary advice on conservation objectives (JNCC 2018a). It should be noted that it was not possible to address all feature attributes as part of this monitoring survey given their comprehensive nature. The feature attributes were therefore rationalised and prioritised and are presented below (Table 1).

Table 1: Feature attributes and supporting processes addressed to achieve report objectives 1 and 2.

Feature attribute	Feature	Outputs
Extent and distribution	Offshore deep-sea muds	PSA point sample distribution and qualitative evidence from imagery analysis.
	Burrowed mud	
	Offshore subtidal sands and gravels	
Physical structure Finer scale topography Sediment composition	Offshore deep-sea muds	PSA and qualitative observations of seabed character.
	Burrowed mud	
	Offshore subtidal sands and gravels	
Biological structure Key and influential species	Offshore deep-sea muds	Multivariate analysis of infaunal and epifaunal communities.
	Burrowed mud	

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[4] http://www2.gov.scot/Resource/0045/00457016.pdf

Feature attribute	Feature	Outputs
Characteristic communities	Offshore subtidal sands and gravels	

1.4.3 Definition of favourable condition

Specific attributes of the features will be monitored and assessed to determine whether conservation objectives have been achieved at the site level. Supplementary conservation advice (JNCC 2018a) for this MPA lists feature attributes for designated features. These attributes fall into broad attribute themes, which align with the terminology used in the Designation Order, and are described below:

Extent refers to the total area within the site occupied by the feature while **Distribution** refers to how a feature is spread out within the site. A reduction in extent has the potential to alter the biological and physical functioning of sedimentary habitat types (Elliott *et al*. 1998). The distribution of a habitat influences the component communities present and can contribute to the health and resilience of the feature (JNCC 2004).

Structure refers to both the physical structure of a subtidal sedimentary habitat and its biological structure. Physical structure refers to: **1. Finer scale topography** and **2. Sediment composition** while biological structure refers to: **1. Key and influential species** and **2. Characteristic communities.**

Functions are ecological processes, e.g. sediment processing, secondary production, habitat modification, supply of recruits, bioengineering and biodeposition. Functions are reliant on the growth and reproduction of characterising biological communities and provide a variety of functional roles within it (Norling *et al.* 2007). These can occur at a number of temporal and spatial scales and help to maintain the provision of ecosystem services (ETC 2011) both locally and to the wider marine environment.

Supporting Processes refers to a range of natural processes to support and help any recovery from adverse impacts. For the site to fully deliver the conservation benefits (JNCC 2018b) these processes, namely hydrodynamic regime, water quality and sediment quality must remain largely unimpeded. While this is a monitorable feature attribute, it is outside the scope of this report as no data on supporting processes were collected during the 1016S survey.

1.4.4 Report aims and objectives

The aim of this monitoring report is to explore and describe the attributes of the features within GSH to enable future assessments of feature condition.

The specific objectives of this monitoring report are as follows (broad attribute themes, as defined in the site Designation Order, are in bold);

- Describe the **extent, distribution, structure and function** of offshore deep-sea muds, burrowed mud, and offshore subtidal sands and gravels within each box surveyed at GSH;

- Compare physical and biological characteristics of Boxes D (inside the MPA) and F (outside the MPA), to determine whether they are suitable control and impact sites for a future before after control impact (BACI) study;

- Evaluate the accuracy of the Hughes *et al.* (2014) biological community zones model within GSH;
- Describe the character and distribution of any Priority Marine Features (PMFs) observed which are not designated features of the site;
- Present any evidence of human impacts, and;
- Recommend future monitoring approaches for the MPA.

2 Methods

2.1 Survey design ‘as planned’

A monitoring survey was conducted at GSH onboard MRV *Scotia* from 18 July to 3 August 2016. The aims of this survey were to:

1. Conduct a Type 1 (sentinel) monitoring survey[5] of GSH focusing sampling within survey boxes positioned to allow for sampling to occur across the range of depths, biological zones (as proposed by Hughes *et al.* 2014) and proposed management measures at the site;

2. Conduct Type 3 (investigative) sampling within a survey box outside of GSH at the same depth with similar current fishing pressure as a survey box within a proposed management measures area in GSH; and

3. Conduct a camera chariot transect and benthic sampling survey within GSH (including within area of existing MBES bathymetry and MBES backscatter data) to gather further information on the distribution of habitats present within the site.

This survey was carried out to form the first time series point (T^0) for monitoring GSH. Table 2 outlines the monitoring hypotheses. There were insufficient prior data to undertake a power analysis to inform the sampling design at this MPA.

A boxed survey design (Table 3, Figure 5 and Figure 6) was used to stratify sampling efforts across the depth gradient at GSH. Boxes were selected along a bathymetric gradient, based on 30 arc second resolution bathymetry for the NE Atlantic (GEBCO 2015), with placement designed to sample to biological zones as proposed by Hughes *et al.* (2014); within each box, core and drop camera samples were assigned using a fixed 3 km triangular grid from a single origin point to collect samples from across the extent of each box in the absence of any existing information within the site. Stations in different boxes could not be closer together than stations in the same box (i.e. >3 km apart). Systematic sampling was used as it is not reliant on high confidence habitat maps and provides more uniform coverage of a survey area than simple random sampling. The systematic grid design can be used to increase the probability that samples represent the whole sampling area when it cannot be reliably stratified, or where confidence in maps is low (Noble-James et al. 2018). Triangular grid patterns are typically preferable to square grids, as this reduces the chance of bias towards a regularly spaced feature (Byrnes 2000; Noble-James *et al.* 2018).

Data were acquired to comprise the ‘Before’ monitoring event in a BACI study to investigate the effectiveness of possible fisheries management measures. The ‘Before-After’ site sample box (D) was positioned in an area of GSH which is currently fished and may be closed to fishing. The ‘Control’ site sample box (F) was positioned to include the same depth range and similar levels of fishing pressure as box D to maximise chances of detecting a change not related to either depth or fishing pressure. Sampling effort was allocated to Box F (Figure 5).

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[5] Definitions of the monitoring types can be found in the UK Marine Biodiversity Monitoring Strategy (Kröger & Johnson 2016).

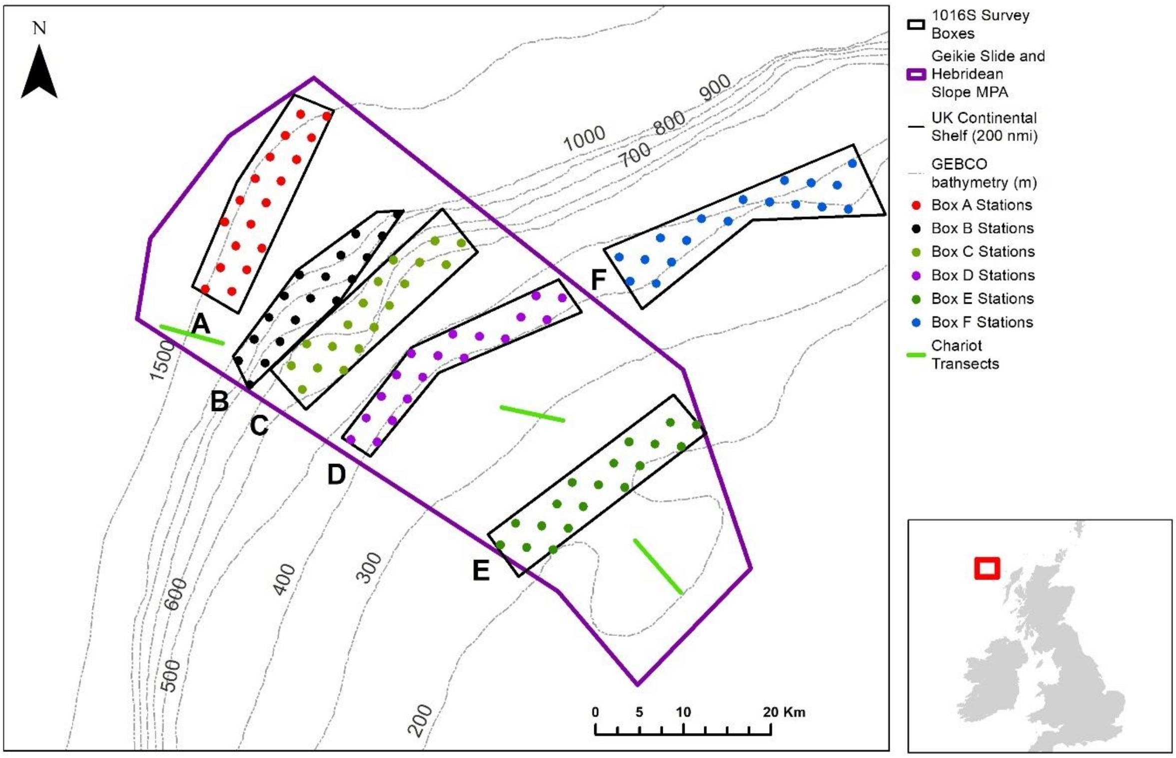

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Figure 5: Survey boxes and sample stations as planned.

Table 2: Monitoring hypotheses.

Type 1 (sentinel) monitoring survey of GSH	
Hypotheses to be evaluated from current dataset	H0: There is no difference (in infaunal or epifaunal metric/trait or community composition) between sampling boxes. H0: There is no difference (in infaunal or epifaunal metric/trait or community composition) within sampling boxes.
Future hypothesis (enabled by collection of a second time point)	H0: There is no difference (in infaunal or epifaunal metric/trait or community composition) in each sampling box between two different sampling events. To achieve Objective 1, benthic samples and drop-frame camera data were acquired at stations positioned within nested sampling boxes across GSH.
Type 3 (investigative) sampling within a survey box outside of GSH	
Hypotheses to be evaluated from current dataset	H0: There is no difference (in infaunal or epifaunal metric/trait or community composition) between control and impact boxes. H0: There is no difference (in environmental parameter i.e. sediment type/organic content/depth/other) between control and impact boxes (i.e. are the boxes comparable for purpose of a future BACI?).
Future hypothesis (enabled by collection of a second time point)	H0: There is no interaction between the ‘Time’ factor (Before/After) and the ‘Box’ treatment factor (Control/Impact) (where infaunal or epifaunal metric/trait is the response variable).

2.1.1 Conduct a camera chariot transect survey to gather further information on the distribution of broad-scale habitats present within the site

Three 3.8 km long camera chariot transects were planned within GSH to achieve this objective. Owing to limited time available on survey and the lower priority of this objective relative to Objectives 1 and 2, one 3.8 km long camera chariot transect was collected. Completing Objective 3 was considered to be of higher priority than completing contingency sampling Box B (see 2.1 above).

Full details of the survey operation are available in O'Connor *et al.* (2016) and details of sample box vertices and sample points are presented in table A15.1.

2.2 Survey 'as executed'

Not all planned stations were completed during the available survey time. Stations were completed in priority order (Table 4: O'Connor *et al.* 2019) while sampling in box E was curtailed due to planned naval operations. Samples were collected in a systematic order to make best possible use of survey time (documented in Annex 1 of the cruise report (O'Connor *et al.* 2019).

Table 3: Summary of boxed survey design and completed sampling.

Sampling box	**Targeted Feature**	**Depth band**	**Hughes *et al.* (2014) Zone**	**Completed Sampling**
A	Burrowed mud	>800 m	Decapod burrowing zone	13 Dropframe camera only stations
C	Offshore deep sea muds	600 – 800 m	*Ophiocten gracilis* zone	3 Dropframe camera only stations 6 Box corer only stations 9 Drop camera and box corer only stations
D	Offshore subtidal sands and gravels / Offshore deep sea muds	400 – 600 m	Upper slope	6 Box corer only stations 12 Drop camera and box corer only stations
F	Offshore deep sea muds	400 – 600 m	*Ophiocten gracilis* zone	6 Box corer only stations 12 Drop camera and box corer only stations
E	Offshore subtidal sands and gravels	200 – 400 m	Outer shelf and shelf break	5 Drop camera and box corer only stations

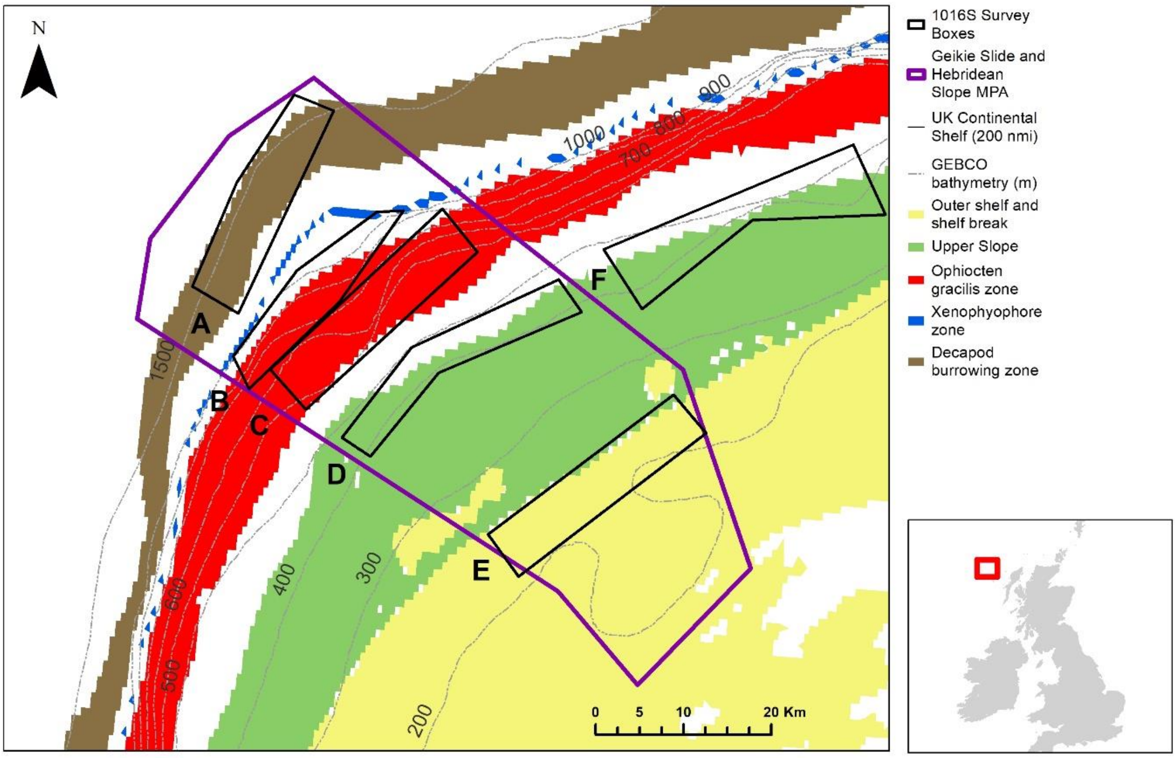

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Figure 6: Location of biological community zones as proposed by the Hughes *et al.* (2014) model and 1016S survey boxes.

2.3 Data acquisition and processing

2.3.1 Sediment sampling

In total, 56 sediment samples for particle size analysis (PSA) and benthic infauna were collected (Figure 7) using a 0.25 m^2 USNEL Mk II-type box corer of Benthic Solutions Limited design.

A sub-sample was taken from each core using a 55 mm diameter acrylic subsampler to a depth of 15 cm and stored at -20°C prior to particle size analysis in accordance with NMBAQC guidance (Mason 2016). The remaining sample was processed to a depth of 15 cm using 0.5 mm and 0.25 mm sieves, stacked sequentially, to extract infauna and examine the different fauna and faunal assemblages retained on each sieve fraction. The sieve fractions were photographed and fixed in 5% buffered formaldehyde.

Please note that the use of a 15 cm subsample has resulted in a significantly increased fraction of mud in samples, which is evident in the subsequent results and discussion.

2.3.2 Seabed imagery

A combination of drop camera (58 tows of 150 m) and chariot (one tow of 3.8 km) imagery was collected during the survey (Figure 7). The drop camera system was composed of a SubC 1 Alpha video camera for primary TV observation and topside recording to mini-DV tape and DVD (HD video recorded internally) with a standard definition Kongsberg OE 14-408 digital camera (10MP) with dedicated flash unit for still images capture (camera controlled topside, images recorded internally). Additionally, four SEA-LED lamps and two reference spot lasers, spaced at 64 mm, were used. Drop camera transects were conducted prior to coring to inform whether or not the station substratum was suitable for physical sampling. The imagery data were collected in accordance with Mapping European Seabed Habitats (MESH) guidelines (Coggan *et al.* 2007).

A detailed breakdown of the survey methodology and equipment used is available in the cruise report (O'Connor *et al.* 2016).

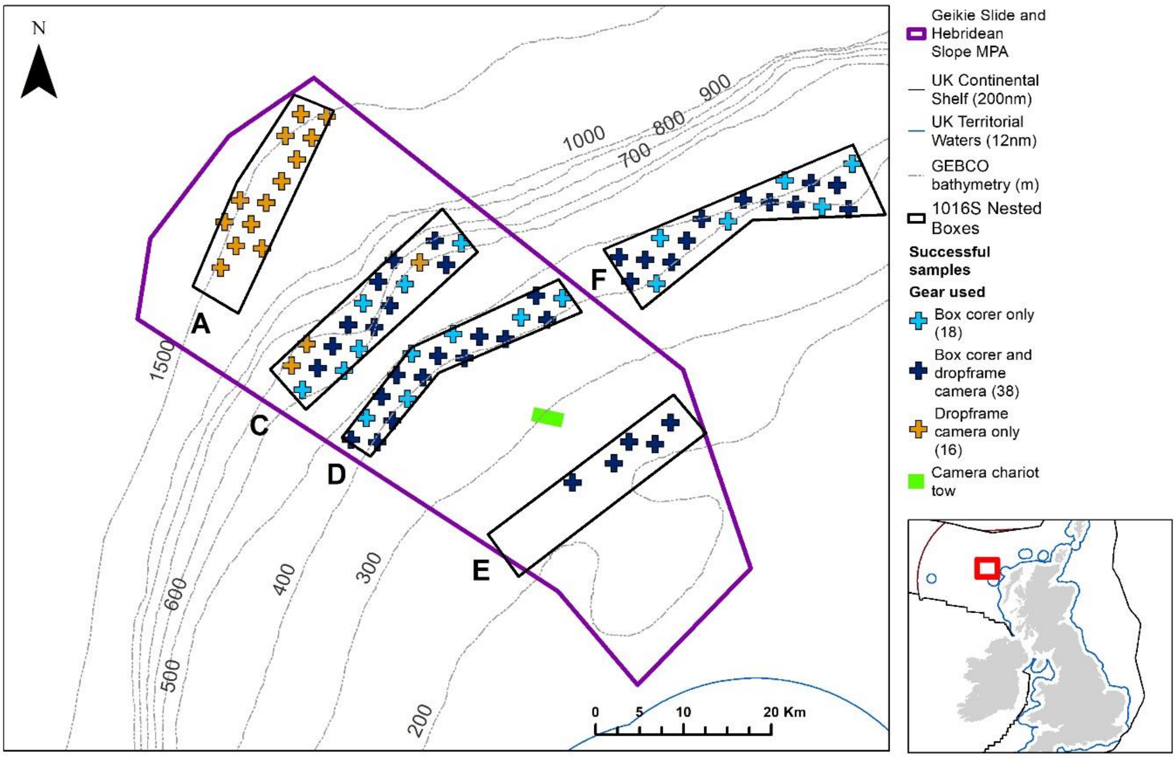

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Figure 7: Completed sampling by gear type.

2.4 Data preparation and analysis

In order to assess the condition of protected features across the UK MPA network in a "common language", habitats have been derived from the designated features of the site (Table 4), based on the Marine Habitat Classification for Britain and Ireland (JNCC 2015). Given the range of depths present at GSH, monitoring habitats are referred to in general terms of mud, sand and coarse sediment rather than specific depth-bounded monitoring habitats to prevent arbitrary division of the dataset and improve readability.

Table 4: Designated PMFs in the Geikie Slide and Hebridean Slope MPA and their corresponding habitats from the Marine Habitat Classification of Britain and Ireland (v15.03).

Designated feature	Corresponding monitoring habitat
Burrowed mud	Atlantic mid bathyal mud
Burrowed mud	Atlantic lower bathyal mud
Offshore subtidal sands and gravels	Atlantic upper bathyal sand
Offshore subtidal sands and gravels	Atlantic mid bathyal sand
Offshore subtidal sands and gravels	Atlantic mid bathyal coarse and mixed sediment
Offshore subtidal sands and gravels	Atlantic lower bathyal coarse and mixed sediment
Offshore deep-sea mud	Atlantic upper bathyal mud
Offshore deep-sea mud	Atlantic mid bathyal mud
Offshore deep-sea mud	Atlantic lower bathyal mud

2.4.1 Sediment particle size distribution

Sediment samples were processed by MSS and CEFAS using the recommended methodology of the North East Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme (Mason, 2016). The <1 mm fraction was analysed using laser diffraction and the >1 mm fraction was dried, sieved and weighed at 0.5 phi (ϕ) intervals. Sediment distribution data were then classified into habitats using a modified version of the Folk classification produced during the MESH project (Long 2006).

2.4.2 Infaunal data preparation

Faunal samples were processed by Thomson Unicomarine and were identified to the lowest taxonomic level practicable, enumerated and batch weighed (blotted wet weight) to the nearest 0.0001 g. This was carried out following the recommendations of the NMBAQC scheme (Worsfold *et al.* 2010). Full details are available in the analysis report (Appendix 1).

2.4.3 Epifaunal data preparation

Video and still imagery were analysed for several parameters:

- To identify habitat
- To identify and quantify epifauna
- To provide semi-quantitative data on seabed characteristics
- To note transitions between substrata
- To record any visually detectable human impacts

In addition, seapen abundance and condition were also to be assessed, but no seapens were observed. *Nephrops* burrows were also counted following the techniques described within guidance provided in the ICES WKNEPHBID report on *Nephrops* burrow identification (Annex 5 (ICES 2008)).

A total of 58 drop camera video tows, one chariot tow and 951 still images were analysed. For quality control (QC) purposes, six video tows, two five-minute sections of chariot tow and 102 stills were re-analysed, both internally by the laboratory and externally. The images were generally of ‘good’ to ‘poor’ visual quality, primarily due to disturbed sediment. Additionally, variable speed of the tow (due to the camera ‘hopping’) made analysis challenging. The stills were of variable quality, often too far from the seabed for detailed identification, especially of cryptic fauna. Full details are available in the analysis report (Appendix 2).

2.4.4 Marine litter and anthropogenic impacts

Where noted in the analysis reports (Appendices 1 and 2), instances of marine litter were classified using Marine Strategy Framework Directive (MSFD) categories (Appendix 4) and anthropogenic impacts are reported.

2.4.5 Numerical and statistical analyses

The following hypothesis were used to inform analysis:

- H^0 There is no difference (in infaunal or epifaunal metric/trait or community composition) **between** sampling boxes.
- H^0 There is no difference (in infaunal or epifaunal metric/trait or community composition) **within** sampling boxes.

Data Truncation

Prior to analysis, both the epifaunal and infaunal datasets were examined and taxa were excluded as appropriate to ensure any erroneous entries were removed and each entry represented a valid taxon. Several checks were applied:

- In instances of a named species recorded together with members of the same genus (i.e. the latter not identified to species level) the entries were merged to genus level (e.g. records of *Lepidasthenia sp.* and *Lepidasthenia brunnea* are merged to *Lepidasthenia sp.*).
- In instances where multiple named species were recorded together with members of the same genus (i.e. the latter not identified to species level) the entries are retained at species level to retain the detail of multiple species of the same genera as well as genus level identification, possibly due to damage to the specimen, rather than uncertainty in the identification (i.e. records of *Glycera spp.* and *Glycera alba, Glycera capitate and Glycera lapidum* are retained *as-is*).

Where taxa have to be merged to a higher taxonomic level than they were originally identified at, a compromise was reached between the information lost by discarding recorded detail on a taxon's identity and the potential for error in subsequent analysis if spurious entries were retained.

- If 'juvenile' records were recorded at the same taxonomic level as 'adult' records then the two records were combined
- If juveniles were recorded at a higher taxonomic level than adults then the 'juvenile' records were removed to avoid having to reduce the taxonomic resolution of the 'adult' records.
- Records of 'eggs' were removed
- Unidentifiable fauna (e.g. Species B, unidentified faunal turf) were removed
- Records of *Vertebrata spp.* and *Cephalopoda spp.* were removed

Due to the nature of the imagery identification at GSH, a large number of identifications were made at a high taxonomic level with very high certainty. As such, the taxon exclusion carried out on epifaunal datasets was minimal.

Full details of the excluded taxa for infauna and epifauna are available in appendices 5 and 6.

Infaunal multivariate analysis

In order to investigate the hypotheses listed above, multivariate analysis was conducted using the statistical package PRIMER (v7: Clarke and Gorley, 2015). Infaunal data from the 0.5mm fraction only were used to calculate summary statistics and univariate indices of community structure: total abundance per box, range of abundances from cores within a box, mean number of individuals across cores, Margalef index and Pielou's evenness. The Margalef index reflects the total number of species relative to the natural log of total abundance while Pielou's evenness reflects the relative abundance of each species, scaled between 0-1 where 1 is perfect evenness.

Prior to multivariate analysis, the dataset was visually examined using shade plots before a fourth root transformation was applied to downweight numerically dominant taxa. Biomass data (instead of abundance) were considered for determining community structure, but this has not been progressed as the observed patterns of clustering and ordination are equivalent for biomass and abundance (Appendix 7). A resemblance matrix was generated using Bray-Curtis similarity and the following analyses were conducted:

- Non-metric multidimensional scaling (nMDS) was used to explore the relationships between samples.
- Similarity profiles (SIMPROF) were used to determine if the dataset has a structure distinct from that derived by random permutation.
- Hierarchical clustering was used in conjunction with SIMPROF to look for divisions in the dataset and to determine where divisions could no longer be made appropriately (i.e. any sub cluster could be randomly permuted).
- Analysis of similarity (ANOSIM) was used to investigate differences between boxes both globally and pairwise.
- Similarity percentages (SIMPER) were used to further investigate the results from ANOSIM and inform which taxa characterised which box, and which taxa explained the dissimilarity (or lack of it) between boxes.
- Biota and/or environment matching (BEST) was used to relate measured environmental factors (depth, sediment type, surface swept area ratio (as derived by Church *et al.* 2016), latitude and longitude) to biological patterns and examine how well these factors (or a combination of them) explain biological variability.

After examining the 0.5 mm fraction and the 0.25 mm fractions were examined using a suite of multivariate techniques. The results and discussion of these results is contained in Appendix 11.

Infaunal biotopes have been assigned where possible using guidance proposed by Parry (2019).

Epifaunal multivariate analysis

In addition to infaunal data, epifaunal data were also analysed. Images of good and excellent quality were randomised within each survey box and aggregated into sample units of approximately 100 individuals each. The resultant sample was then divided by the total field of view observed in each sample unit to standardise across sample units that consisted of different numbers of images. This matrix was then analysed in the same manner as the infaunal data, with any variation noted in the corresponding results section. It is important to note the reduced taxonomic resolution available from imagery data. This is due to reasons such as poor visibility, variable speed and altitude of the camera during the tow, cryptic fauna and the difficulties in identifying some taxa to lower taxonomic levels without the physical specimen present. The implications of this reduced resolution are discussed below.

Epifaunal biotopes have been assigned where possible using guidance proposed by Parry (2019).

Environmental factor analysis

Where possible, environmental factors have been used to examine the drivers behind observed structure in biological communities. These factors include depth, particle size distribution, surface swept area ratio (as derived by Church *et al.* 2016) and location (expressed as latitude and longitude) and were individually examined for correlation and distribution using a resemblance measure and draftsman’s plots then transformed where appropriate.

3 Results

3.1 Benthic habitat extent and distribution

3.1.1 Particle Size Distribution (PSD)

The 56 successful box core sediment samples taken in and adjacent to GSH yielded 49 samples classified as mud and seven classified as mixed sediments. Results from PSD show several trends of interest. Firstly, the distribution of mud habitats is much greater than previously predicted (Figure 8). Of the predicted habitats including mud and mixed sediments at the base of the slope (Box C), sand on the slope proper (Boxes D and F) and coarse sediment towards the continental shelf (Box E), only the first of these (mud and mixed sediments at the base of the slope (Box C)) was observed in box corer PSD results.

Table 5: Breakdown of habitat type within the MPA boundary (In = Boxes C, D, and E) and outside the MPA boundary (Out = Box F) from box corer PSD.

Habitat	**Box Corer PSD**	
	In	**Out**
Coarse sediment	0 (0%)	0 (0%)
Sand	0 (0%)	0 (0%)
Mud	35 (92%)	14 (78%)
Mixed sediments	3 (8%)	4 (22%)

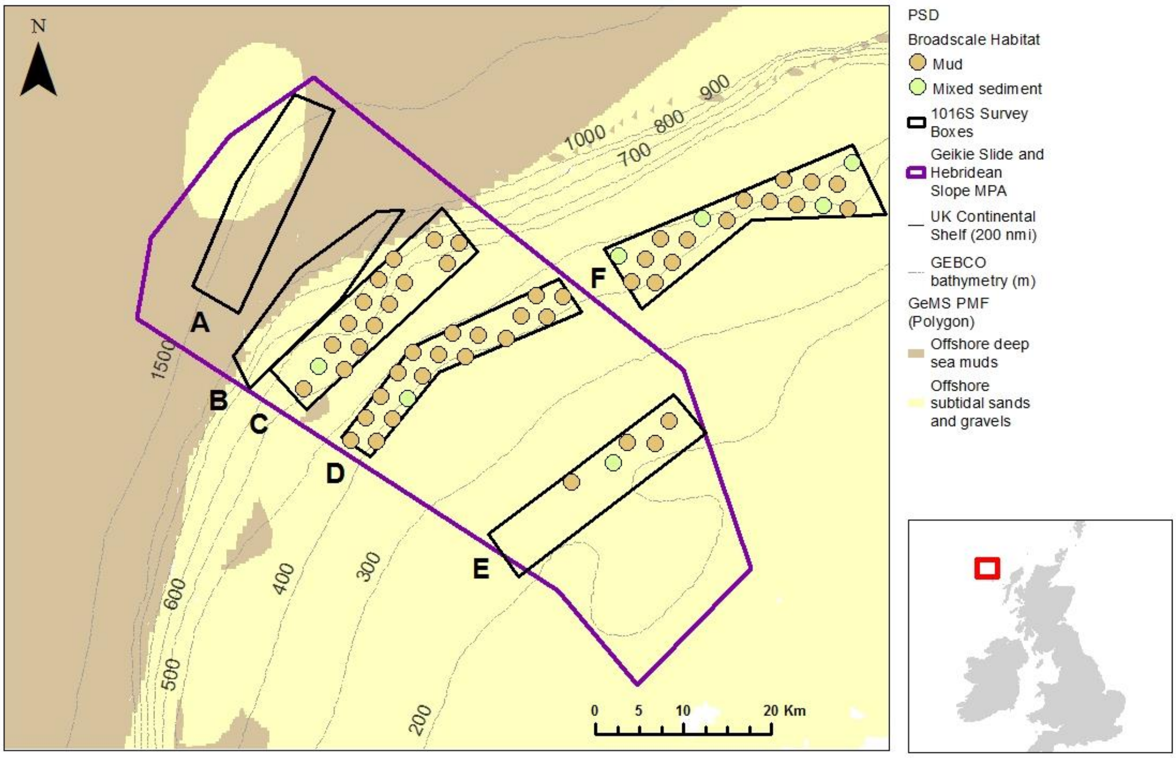

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Figure 8: Habitat classification of box corer samples. Background mapping of PMFs is from GeMS (v5). PSA samples form 1016S are displayed as points where collected.

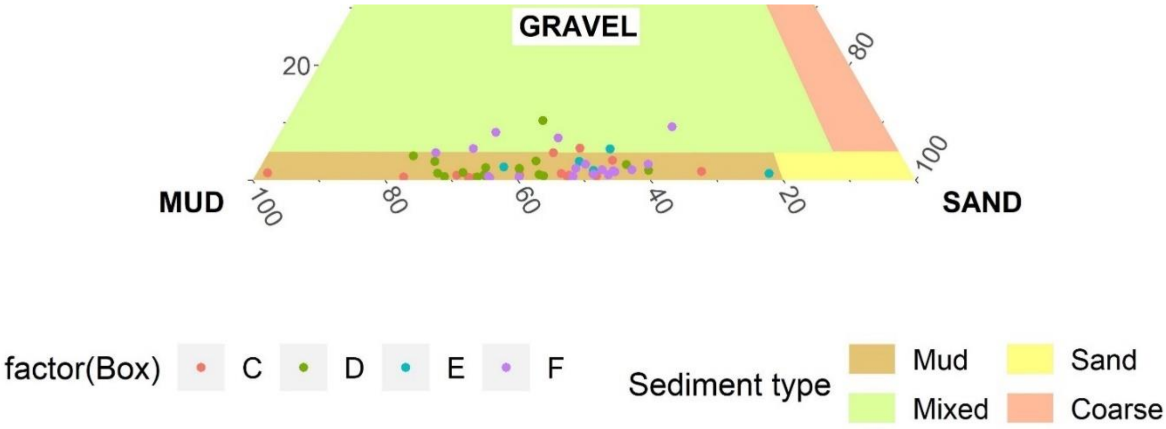

Figure 9: PSD trigon of corer samples cropped to 30% gravel. Background colour refers to habitat classification while point colour refers to sample box.

A comparison of the relative fractions of gravel, sand and mud (>2 mm; <2 mm and >0.063 mm; <0.063 mm, Figure 9) shows that mud is the dominant fraction for the majority of samples taken. When compared against depth (Figure 10), it appears that when moving into deeper water there is a weak trend towards the increasing percentages of fine sediment, except below depths of 800m, where the percentage of fine material drops to below 55 %. It is notable that this result will be highly dependent on the sediment horizon sampled (0-15 cm).

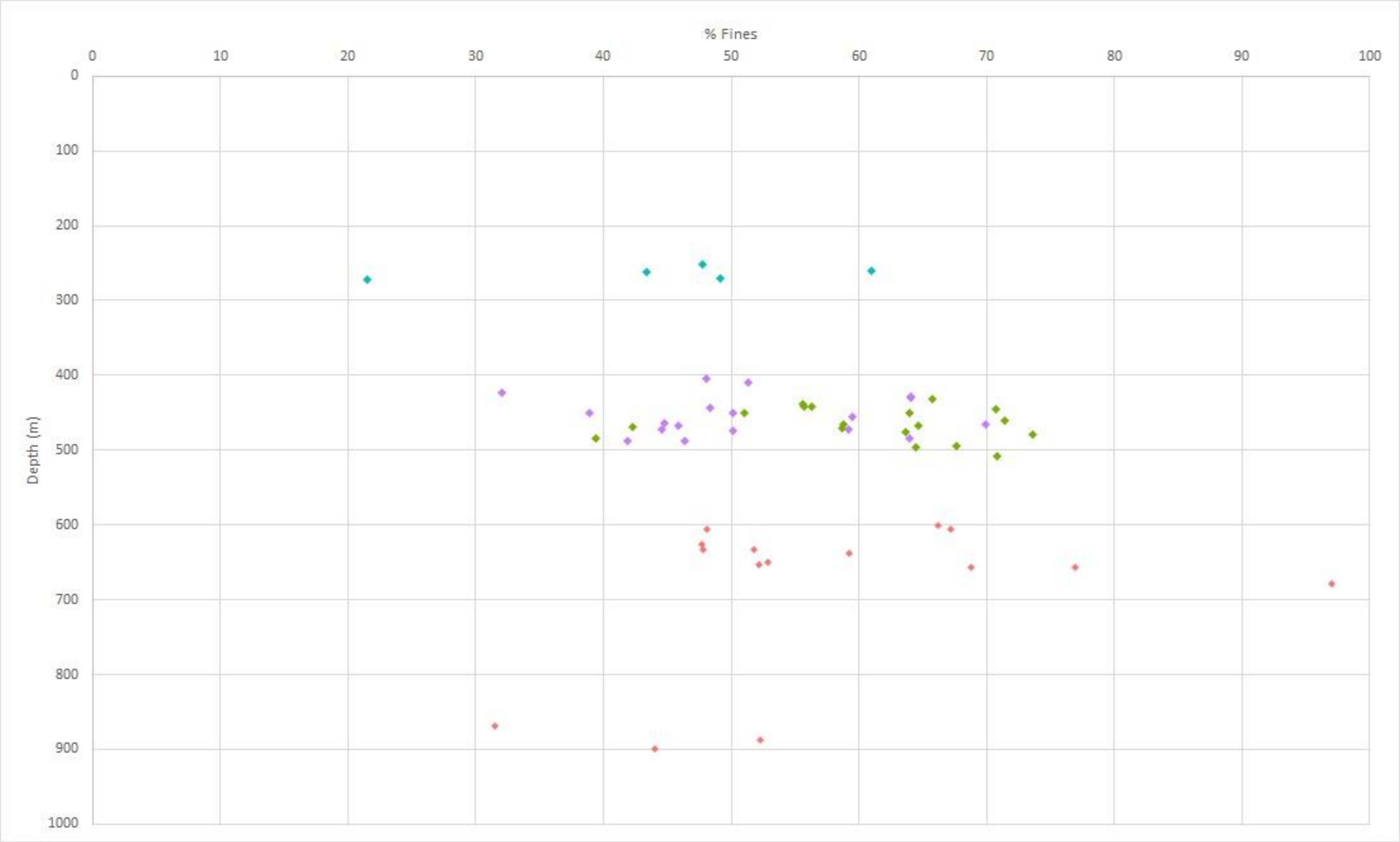

Figure 10: Percentages of fine sediment (<64µm) in core samples against depth. Colour indicates the survey boxes: pink = C, green = D, turquoise = E and purple = F.

In addition to PSD data, field observations from box core samples provide valuable insight into the physical structure of the seabed in and adjacent to GSH. Field observations recorded for each sample included a general description, evidence of layering, colour, smell, conspicuous fauna, surface structures (such as tubes or burrows) and presence of any anthropogenic impacts.

Notably, in and adjacent to GSH, layering of the sediment was common. Across all boxes, 40 of the 56 samples (71%) had evidence of sand layered on top of finer sediments from field descriptions and photographs (Appendices 8 and 9). Within boxes, Box F showed the greatest number of layered samples (17 out of 18, 99%), while Box E had the fewest layered samples (2 out of 5, 40%). Boxes C and D showed intermediate counts of layered samples (8 out of 18, 44% and 14 out of 18, 78%, respectively). Furthermore, the presence of dropstones was observed in numerous samples (Examples in Appendix 9).

3.1.2 Imagery sediment description

From video imagery, both inside and outside the site boundary, there are much greater proportions of coarse sediment (74% inside, 100% outside) and sand (22% inside) than measured from core samples (Figure 11).

Imagery data provides some insight into finer scale topography. From video data, ripples were noted at stations A10, A16 and C13. From still imagery, 54 out of 956 images showed ripples, with 24 images noted for the presence of tubes. At the majority of stations, no ripples or finer scale topography features were observed. The presence/absence of burrows is discussed below in Section 3.3.4.

Table 6: Breakdown of habitat type within the MPA boundary (Boxes C, D, and E) and outside the MPA boundary (Box F) from drop-camera imagery.

Habitat	**Video**		**Stills**	
	In	**Out**	**In**	**Out**
Coarse sediment	34 (74%)	12 (100%)	491 (64%)	119 (62%)
Sand	10 (22%)	0 (0%)	208 (27%)	57 (30%)
Mud	1 (2%)	0 (0%)	57 (8%)	14 (7%)
Mixed sediments	1 (2%)	0 (0%)	9 (1%)	1 (1%)

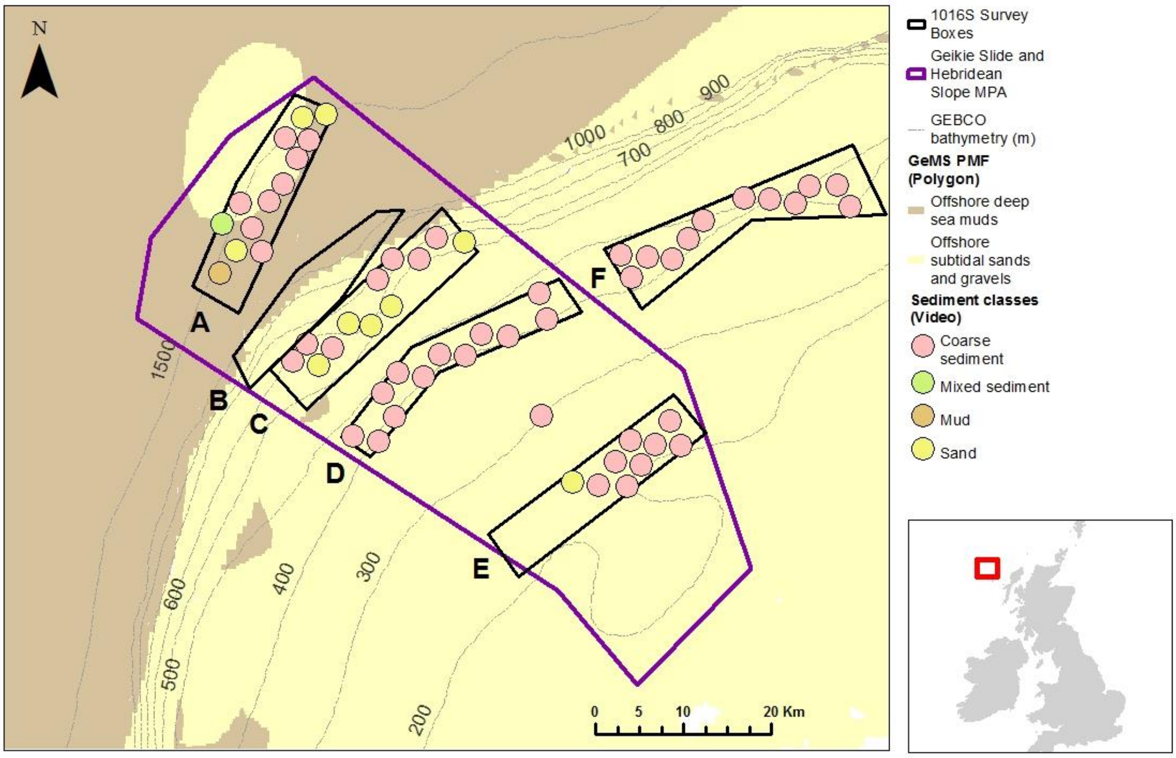

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Figure 11: Habitat classification of box video imagery. Background mapping of PMFS is from GeMS (v5). Video transects from 1016S are displayed as points where collected.

3.1.3 Offshore deep-sea muds and burrowed mud

PSD results show that the extent of this feature (Figure 8) is greater within the sample boxes than previously indicated from predictive mapping. Whilst no PSA samples were taken in Boxes A or B, samples from Boxes D, E and F are not consistent with the predicted classification and only samples from the southwest of box C agreed with the predicted classification. In Box C, mud was found throughout the box, with a single sample classified as mixed sediments. Within Boxes D and F, sand is present in some samples, although not in sufficient proportions compared to mud to be classed as a sand sample (9:1 ratio required, Figure 9), resulting in a majority mud classification. There are however some exceptions, notably in Box F, where 12 of the 46 cores are classified as mixed sediments. Within the shallowest box sampled by the box corer, Box E, there are several samples where there is a moderate proportion of sand evident in the cores (Figure 10).

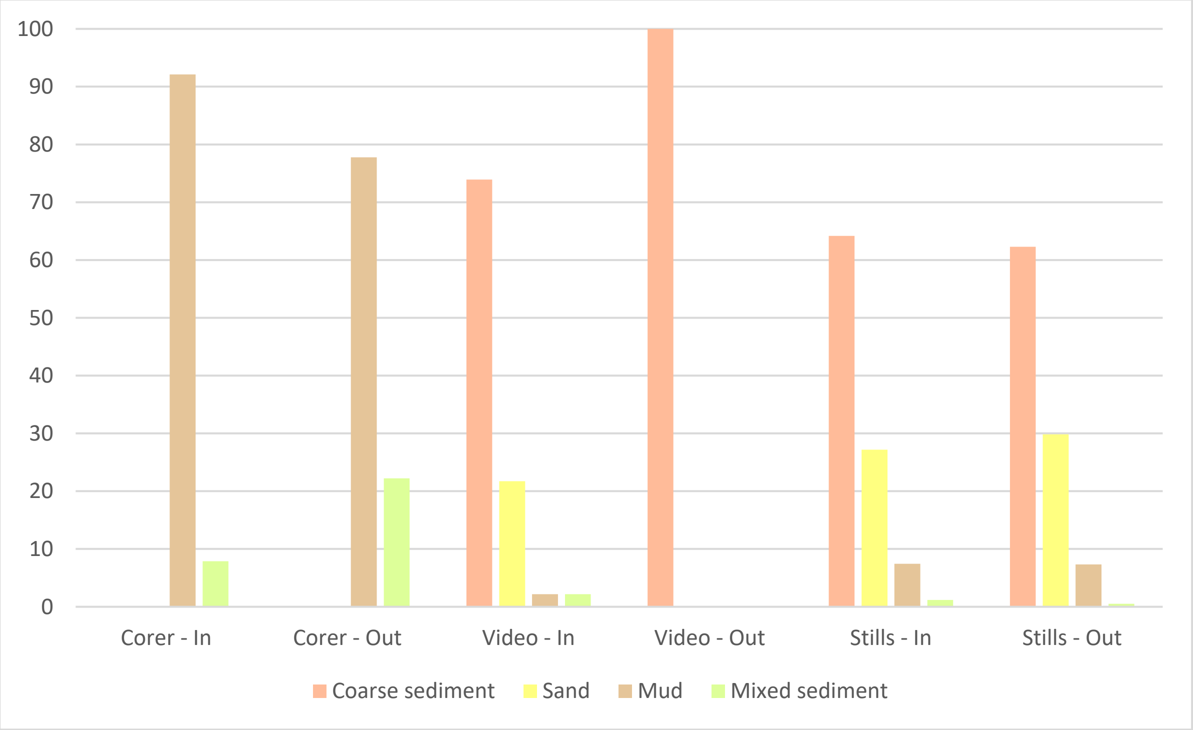

Figure 12: Proportions of samples classified by habitat across gear types both within and outside the site boundary.

While four of the five samples in Box E are classed as mud, it should be noted in Figure 10 that there is a range of sand and mud proportions in Box E cores.

Notably, the visual classification of substrata differs markedly from PSA results. From PSA results, the description of coarse sediment and sand far outweighs descriptions of mud in both video and still imagery (Figure 12).

3.1.4 Offshore subtidal sands and gravels

There are some areas of coarse and mixed sediment, both within and outside the MPA boundary. Additionally, small sand and coarse sediment fractions are present within samples described as mud. Of the 56 cores, seven were classified as mixed sediment and none were classified as coarse sediment, up to 10% coarse sediment was present in some samples (Figure 10).

3.2 Infaunal community analysis

3.2.1 Site level description

From the 56 box core samples, a total of 14,674 individuals were collected in the 0.5 mm sieve fraction. Summary statistics (Table 7) show that descriptive statistics of density and diversity indices remain broadly consistent throughout the site (Boxes C, D and E) and outside the site boundary (Box F), with the exception of slightly elevated faunal density in boxes D and E relative to boxes C and F.

Table 7: Summary statistics from infaunal communities by box.

Box	Samples (n)	Mean no. of individuals per m^2	SD of individuals per m^2	Maximum no. of taxa in any single core	Mean number and SD of species collected	Mean Margalef index	Mean Pielou's evenness
C	15	67.95	15.93	102	76 ± 18.04	13.70	0.83
D	18	77.04	14.69	117	96 ± 8.62	16.72	0.90
E	5	71.20	23.73	89	70 ± 12.19	12.52	0.76
F	18	66.40	10.81	103	91 ± 7.83	16.25	0.91

While biomass was not used to examine community structure, abundance-biomass curves were plotted for each surveyed box (Figure 13). In all boxes, biomass is dominated by fewer species than abundance. Conversely, dominance is spread among a greater number of species, with no one species more than 20% dominant by abundance (Box E). In Boxes D and F, no single species is more than 5% dominant by abundance, highlighting a more even community as seen in Pielou's evenness measures (Table 6).

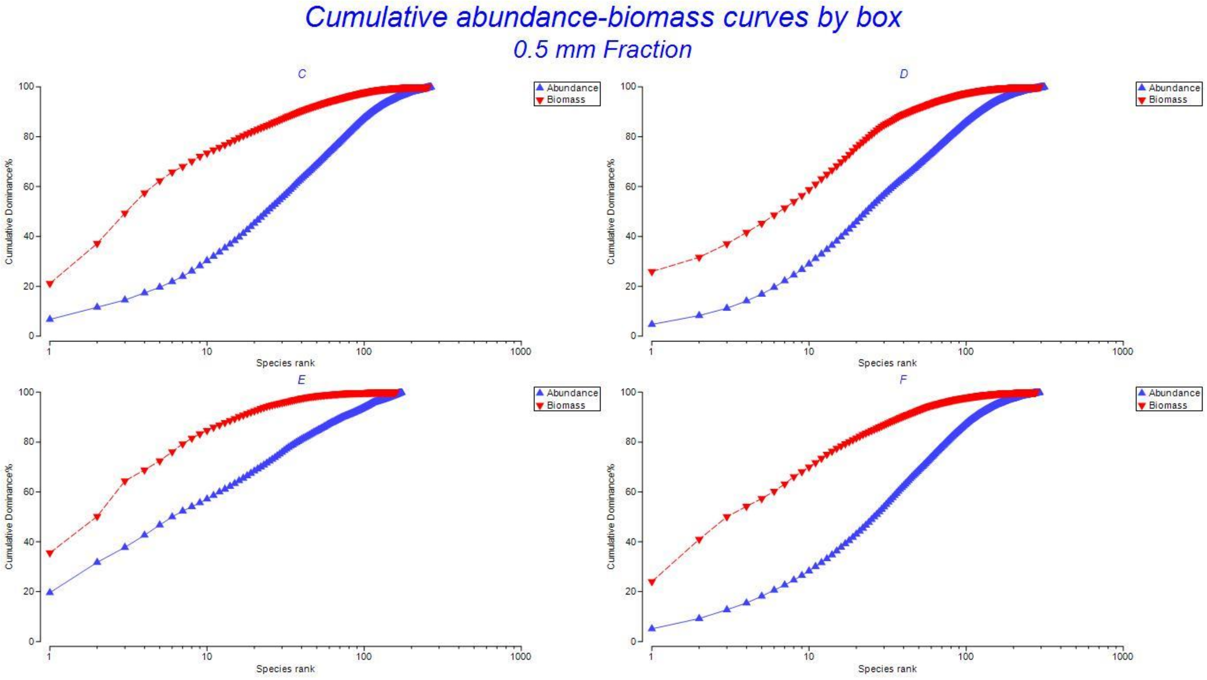

Figure 13: Cumulative abundance-biomass curves by box for the 0.5 mm fraction.

3.2.2 Inter-box and intra-box variability

When examining the structure and function of infaunal communities in and adjacent to GSH it is desirable to assess how variable communities are between sites (inter-box variability) and within each site (intra-box variability). Understanding the former will allow us to look at what drives any observed variation (what fauna is located where) and why that is (why are they located there?). Understanding the latter will allow us to look at smaller scale structure (how different are communities when other factors remain the same?) and how this scale is relative to any observed site-wide gradient.

Results from non-metric multidimensional scaling (nMDS) ordination are shown in Figure 14. Infaunal samples taken from the shallower waters (200-400 m) in the east are distinct from deeper samples (Box E) while those taken from the slope areas (400-600 m) in both the centre of the site and outside the boundary (Boxes D and F) are also tightly clustered on their own. Samples from the deepest area surveyed (Box C) show much greater intra-sample variability than any inter-box variability which can be attributed to a separation between samples collected from below 800 m (seen as blue squares in the top left of Figure 14) and those collected from 600-800 m (seen as red triangles in Figure 14). While there is some evidence of examinable substructure, this should be considered carefully to avoid over-interpretation. The 2D stress value of 0.14 indicates that the 2D representation of the multidimensional scaling ordination is appropriate for interpretation and that the observed structure is a valid representation of the data. Additionally, the use of ANOSIM supports the interpretation that, globally, boxes are distinct (Global R = 0.596, P<0.001). Further examination using pairwise testing (Table 8) supports the interpretation that boxes are all distinct from one another (P<0.001 in all cases), however separation between Boxes D and F (R = 0.219, P<0.001) and Boxes C and D (R = 0.623, P<0.01) is of a lesser magnitude than in other cases.

Table 8: Pairwise ANOSIM tests on infaunal communities between boxes.

Box pairing	R Statistic	Significance level	Actual permutations
C, D	0.623	<0.001	999
C, E	0.983	<0.001	999
C, F	0.710	<0.001	999
D, E	0.998	<0.001	999
D, F	0.219	<0.001	999
E, F	0.996	<0.001	999

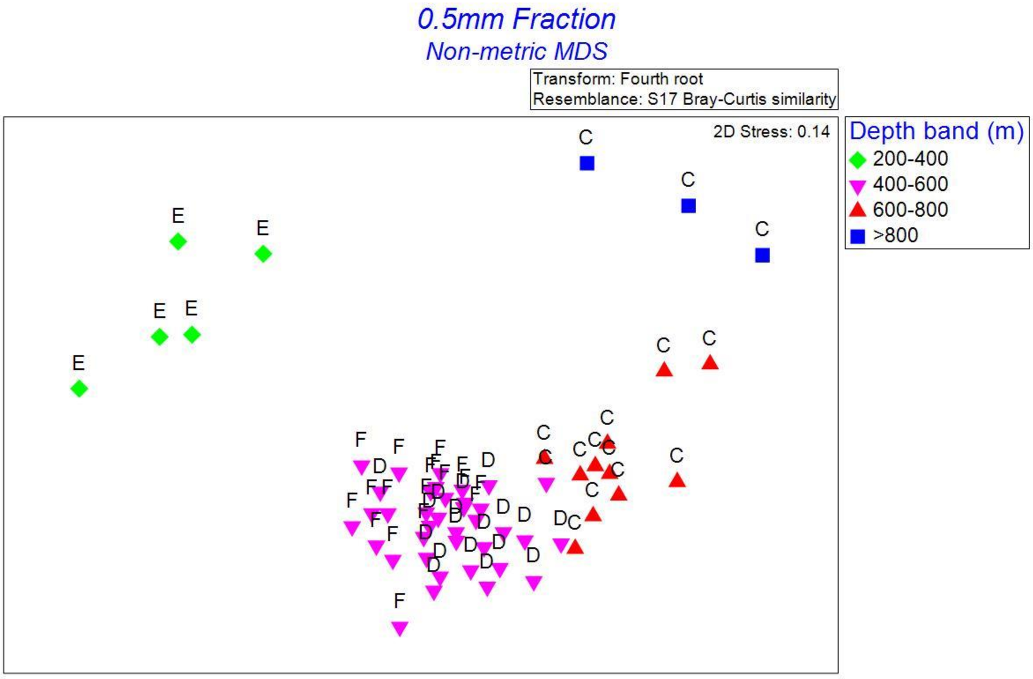

Figure 14: nMDS plot of fourth root transformed 0.5 mm infaunal abundance data.

Understanding that boxes are globally distinct, although with varying degrees of separation (Table 8, Figure 14), we can use SIMPROF and clustering methods to further examine the structure (or lack thereof) within the dataset and individual samples. The dendrogram representing the 0.5 mm infaunal fraction (Figure 15) appears to support the interpretation that survey Boxes E and C are distinct, and that Boxes D and F are mixed. However, similarity between clusters is low; the greatest separation is between Box E and all other samples at a similarity of approximately 30%. Further analysis of Box E shows that any further interpretation of substructure is inappropriate for Box E samples (i.e. any permutation of the samples would yield the same clustering). Within the deepest infaunal samples, collected in Box C, there is limited structure to interpret. While S15, S13, S26 and S7 are only 40% similar to other samples from Boxes C, D and F (as seen in the top right of Figure 15), all other samples are approximately 45% similar or greater. While these samples are distinct at this level, further examination of substructure is not valid. Within Boxes D and F there are few robust clusters, with the majority of samples being freely permutable.

Furthermore, the cophenetic correlation derived from this clustering routine is 0.90 (scaled between 0 and 1, where 1 is a perfect representation of the underlying resemblance matrix). This means that while Figure 15 can be considered a very good representation of the underlying resemblances, it is not perfect and should be interpreted carefully, especially given the significant depth gradient at the site (see BEST analysis below).

Using a similarity percentages routine (SIMPER) allows us to delve into which taxa drive the observed patterns in Figure 14 within boxes (intra-box variability). Average similarity within boxes (Table 9) is generally low, ranging from 53.26 (Box F) to 43.67 (Box E). Full SIMPER results (available in supplementary materials) reveal that in all cases, the average similarity is driven by changes in relative abundance of many species, rather than the presence o absence of any particular species. Across boxes, changes in the relative abundance of a very diverse range of taxa, from cnidarians (Box F) to amphipods (Box D) contribute to similarity. The trend continues for other taxa that contribute to similarity, which are wide ranging across boxes, although absolute contribution to similarity remains low in all cases.

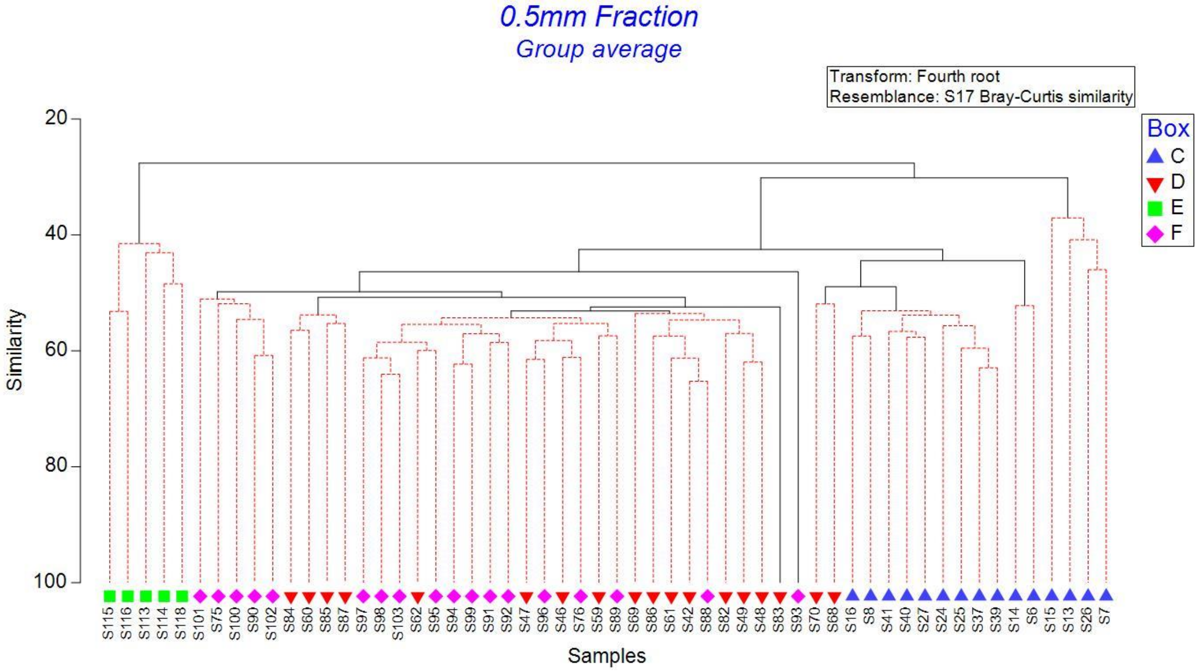

Figure 15: Hierarchical agglomerative clustering with group average on 0.5 mm infaunal abundance data by station, labelled with boxes. SIMPROF results are shown by either black solid or red dashed lines.

Table 9: Summary SIMPER statistics from fourth root transformed 0.5 mm mesh infaunal data within boxes.

Box	Average similarity	Primary contributors (%)
C	44.22	Naticidae spp. (4.17) Bivalvia spp. (3.77) Echinidea spp. (3.55)
D	51.76	*Byblis gaimardii* (2.56) Myodocopida spp. (2.52) Cnidaria spp. (2.47)
E	43.67	Oweniidae spp. (6.25) Ophiuridae spp. (4.28) *Urothoe sp.* (3.98)
F	53.26	Cnidaria spp. (2.80) *Ophiocten abyssicolum* (2.67) Asteroidea spp. (2.58)

When compared to a range of environmental variables (depth, latitude, longitude, % gravel, % sand, % fines and surface swept area ratio (Church *et al.* 2016)) using BEST analysis (Table 10), several patterns are evident. The measured environmental data is significantly different from permuted results (Rho = 0.868, P = 0.01) and water depth is both the best single and grouped explanatory variable (Rho = 0.868). This indicates a strong correlation of change in communities and change in depth (i.e. 86.8% of the variation in community is explained by water depth) which is clearly observable in Figure 14. Notably, the addition of more variables explains less of the variation than using water depth alone.

Table 10: BEST result for each number of variables between boxes. Surface SAR refers to seabed surface swept area ratio (Church et al. 2016).

Number of Variables	Correlation (Rho)	Variables
1	0.867	Water depth
2	0.801	Water depth, % Sand
3	0.722	Water depth, % Sand, Surface SAR
4	0.675	Water depth, % Sand, % Fines, Surface SAR
5	0.641	Water depth, Longitude, % Sand, % Fines, Surface SAR

This is contrasted by the BEST results looking at intra-box variability. Depth is a poor (Rho = 0.345) explanator of variability across depth and the best possible combination of variables is a combination of depth, longitude and % fines (Rho = 0.356).

3.2.3 Infaunal Biotope classification

Assigning level 4 (Community level) biotopes in and adjacent to GSH is challenging for two reasons: the lack of deep-sea specific infaunal biotopes and a very extensive taxon list (~470 taxa) where many species are represented by few (<5) individuals across the site and many samples are dominated by ubiquitous polychaetes (e.g. *Glycera spp.,* 375 individuals across all samples) (Figure 16).

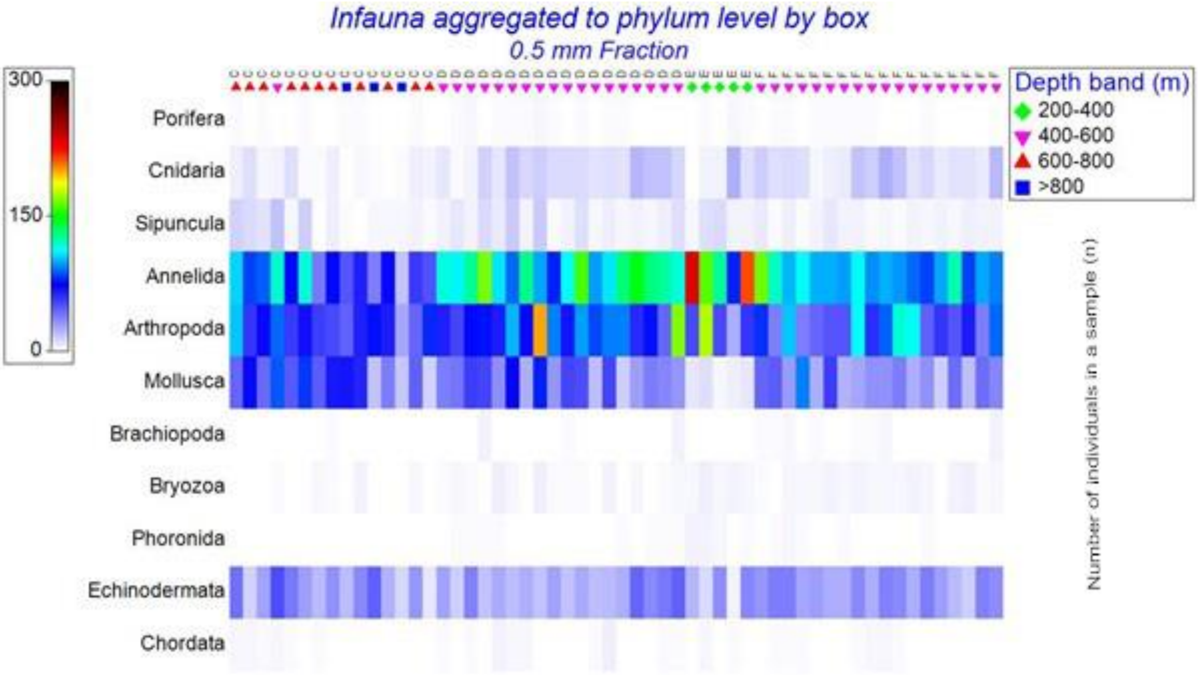

Figure 16: Shade plot of infauna aggregated to phylum level from the 0.5 mm fraction.

Within the shallowest box, box E, the community is characterised by 174 taxa, the most abundant of which are owenid polychaetes (19.5 % of all fauna), copepods (12.1 %) and *Pseudopolypora sp.* (6.0 %). Other important taxa are taxonomically diverse and include ophiuroids, the amphipods *Ampelisca truncata* and *Urothoe sp., Ditrupa arietina,* cnidarians and a range of polychaetes. This represents an unusual combination of polychaete and amphipod/copepod communities with a range of other fauna in a matrix. Notably, bivalves are rare within samples taken from box E.

Within the deeper boxes D and F, there is a trend to greater number of taxa contributing to the makeup of the community. Copepods, bivalves, polychaetes, naticidae and high-level identifications of cnidarians are all prevalent in the taxa. Both boxes show an elevated taxa count (Box D 317, Box F 296) relative to box E.

In contrast, samples taken from box C are not dominated by any one taxon. Bivalves are the most dominant taxon, making up 5.5 % of the community. Additionally, highlighting the highly diverse fauna present in box C, 251 taxa make up 50 % of the community.

While there are limited existing infaunal biotopes that could be assigned to the communities found in and adjacent to GSH, the existing deep-sea level 4 biotope of ‘Mixed infauna dominated by polychaetes in Atlantic mid bathyal mud’ (M.AtMB.Mu.InfPol) is the most appropriate existing biotope in muddy sediments. A proposed extension of this biotope to upper bathyal depths and mixed sediments (M.AtUB.Mu.InfPol, M.AtUB.Mx.InfPol, M.AtMB.Mu.InfPol) would be an appropriate option to biotope the remaining infaunal samples across all boxes.

As many of the component species of the PMFs are not reliably sampled in infaunal samples, it is prudent to interpret the distribution of biotopes pragmatically and in combination with other sources of data, such as biotopes derived from imagery in Section 3.4.5.

3.3 Epifaunal community analysis

3.3.1 Summary statistics and description

In order to assess the composition, variability and diversity of epifauna within and adjacent to GSH, still images only have been used. Within the still imagery several broad patterns are evident (Table 11). Faunal density is much lower in Box E than in other boxes, although it is pertinent to note that there are only three sample units in Box E and a large number (2,594) of *Ditrupa arietina* shells have been excluded as it cannot be determined if they are alive or dead from the imagery. Denser fauna was observed at Boxes A and C with the greatest faunal density observed in Boxes D and E. Across boxes A, C and D, mean Margalef's index and Pielou's evenness remain broadly consistent (Table 11). Within Box F, there is reduced richness (5.64) and evenness (0.32) with slightly greater values observed in Box D (richness = 7.32, evenness = 0.74). Within Box E, there is greatly elevated richness (likely an artefact of the small sample size) and moderately high evenness.

Table 11: Summary statistics from epifaunal communities derived from still imagery by box.

Box	Number of stills	Number of samples units	Mean and Range of individuals in a sample unit	Mean field of view and standard deviation in a sample unit	Mean faunal density (n/m^2) and standard deviation in a sample unit	Mean Margalef index	Mean Pielou's evenness
A	105	7	110 (98-147)	23.52 ± 6.76	5.14 ± 2.13	8.10	0.65
C	91	5	109 (99-141)	33.30 ± 16.61	3.90 ± 1.79	8.75	0.59
D	186	14	102 (49-149)	18.38 ± 6.35	6.36 ± 3.03	7.32	0.45
E	100	3	79 (37-100)	46.67 ± 20.55	1.68 ± 0.07	13.00	0.74
F	153	11	104 (98-119)	16.73 ± 3.30	6.43 ± 1.16	5.64	0.32

3.3.2 Inter-box and intra-box variability

From the 40 sample units generated from still imagery collected at GSH, we can examine how variable epifaunal communities are both within boxes (intra-box) and across the site (inter-box) and across depth. Referring to nMDS results (Figure 17) there are clear groupings of sample units from Box A (>800 m) and Box C (600-800 m). Boxes D and F (i.e. samples from 400-600 m) how less separation and samples from the 200-400 m range in box E show separation from other samples but also show large inter-sample variability. It is also notable that elevated stress (0.19) may make interpreting the separation between closely aligned samples challenging. Global ANOSIM reveals that there is a significant difference between boxes (R=0.932, P<0.001).

CLUSTER and SIMPROF tests show that the dataset has structure that is significantly different than expected through permutation (π = 3.401, P<0.001) and while samples are freely permutable within boxes, each box is a distinct SIMPROF cluster (Figure 17). This is distinct from infaunal results, where samples from boxes D and F in the 400-600m range are for the most part freely permutable. Pairwise testing shows that the differences between box pairings are significant throughout, with the weakest effect of observed between boxes D and F (Table 12, in **bold**).

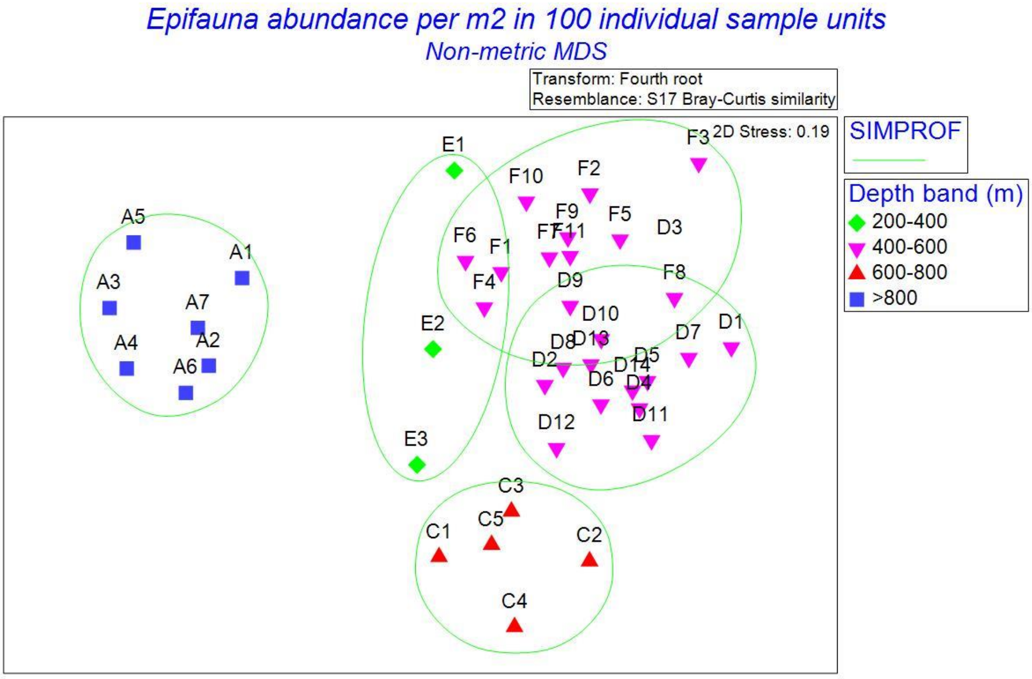

Figure 17: nMDS plot of fourth root transformed epifaunal community data derived from still imagery aggregated by tow and plotted by box.

Table 12: Summary ANOSIM pairwise testing from statistics from fourth root transformed drop camera stills epifaunal data.

Box pairing	**R Statistic**	**Significance Level**
A, C	1	<0.001
A, D	1	<0.001
A, E	1	0.008
A, F	0.994	<0.001
C, D	0.962	<0.001
C, E	1	0.018
C, F	0.950	0.002
D, E	0.952	0.002
D, F	0.782	<0.001
E, F	0.923	0.003

Investigating the drivers behind intra box similarity, SIMPER results (Table 13) show that moderately high (62.26-73.20) similarity within boxes is controlled by differences in relative abundances of a few species (ophiuroids, pagurid crustaceans, echinoids and serpulids). The pattern of few taxa contributing to a given level of similarity contrasts with infaunal samples, where many taxa contribute small amounts to a given level of similarity. This poor resolution results in a greater ‘presence/absence’ structure than in the more detailed infauna dataset and shapes the results based on the presence/absence of taxa rather than by relative abundances of a greater number of individual taxa.

Table 13: Summary SIMPER statistics from fourth root transformed drop camera stills epifaunal data.

Box	Average Similarity	Primary contributors (%)
A	73.20	Polychaeta spp. (12.92) Xenophyophoridea spp. (12.40) Ophiuroidea spp. (12.13)
C	62.26	Ophiuroidea spp. (18.05) Serpulidae spp. (13.91) Echinoidea spp. (11.35)
D	68.41	Ophiuroidea spp. (20.35) Serpulidae spp. (13.30) Echinoidea spp. (8.81)
E	67.88	Serpulidae spp. (15.97) Ophiuroidea spp. (13.90) Paguridae spp. (12.54)
F	67.29	Ophiuroidea spp. (32.41) Serpulidae spp. (18.83) Paguridae spp. (13.47)

3.3.3 Chariot imagery

A single tow was conducted at GSH using a camera chariot (Figure 7). This was to identify benthic habitats on a wider scale than drop camera imagery and provide high level faunal identification over a wide area. This tow was described as coarse sediment and is notable for containing large numbers of anthozoans (1175 individuals), *Parastichopus tremulus* (100) and numerous fish. All highly mobile species observed are listed in Table 14.

Table 14: Abundance counts and SACFOR values for highly mobile species observed during the chariot video tow.

Species	Abundance	SACFOR
Actinopterygii spp. (Other bony fish)	53	Occasional
Scyliorhinus sp.	8	Occasional
Teuthida spp.	1	Rare
Helicolenus dactylopterus	2	Rare
Pleuronectiformes spp.	27	Frequent
Phycis blennoides	3	Occasional
Molva dypterygia	2	Rare

3.3.4 Burrow analysis

No seapens were detected during the analysis of imagery from GSH. Numerous *Nephrops norvegicus* burrows were identified. *Nephrops norvegicus* burrows were identified in 14 video tows, notably in Box C where 9 out of 12 samples contained these burrows. It should be noted that to identify a burrow as *Nephrops*, the characteristic T-shaped burrow or large, crescentic openings and track marks need to be observed. All other holes, small and large (including uncertain *Nephrops* burrows) were recorded separately as ‘other burrow openings’. Other burrow openings were much more abundant, with 1417 recorded across all video tows, with a maximum of 296 burrow openings recorded at station A02. When the distribution of burrows is considered (Figure 18 and Figure 19) it is clear that where burrows are present in a tow, there are greater densities of burrows in the deeper areas of the site, namely Boxes A and C and, conversely, fewer burrows in the shallower areas in Boxes D and F, and very few in the shallowest box, Box E (Figure 18). Notably, in the deepest areas surveyed in Box A, there are seven tows with an absence of burrows, but where burrows are observed they tend to occur in elevated densities relative to the rest of the site.

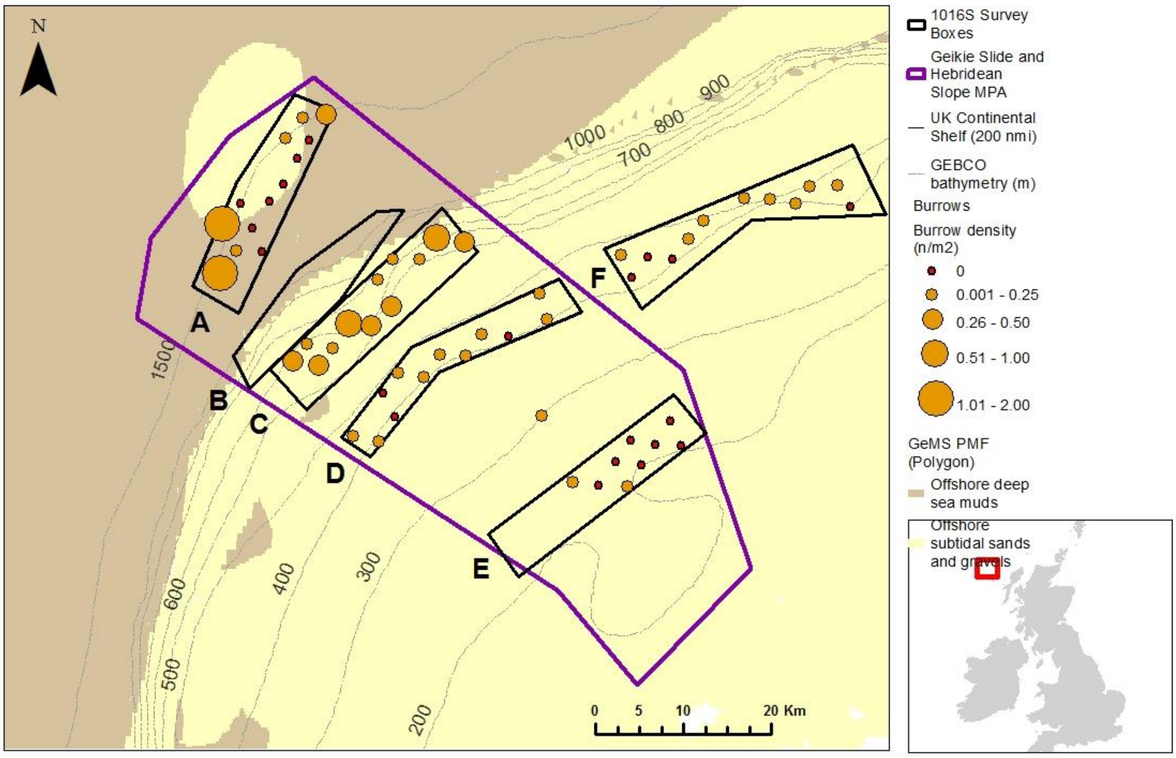

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Figure 18: Density of burrow openings (n/m2). Symbols are scaled by abundance and red dots with a black border indicate an absence of burrows. Background mapping of PMFS is from GeMS (v5).

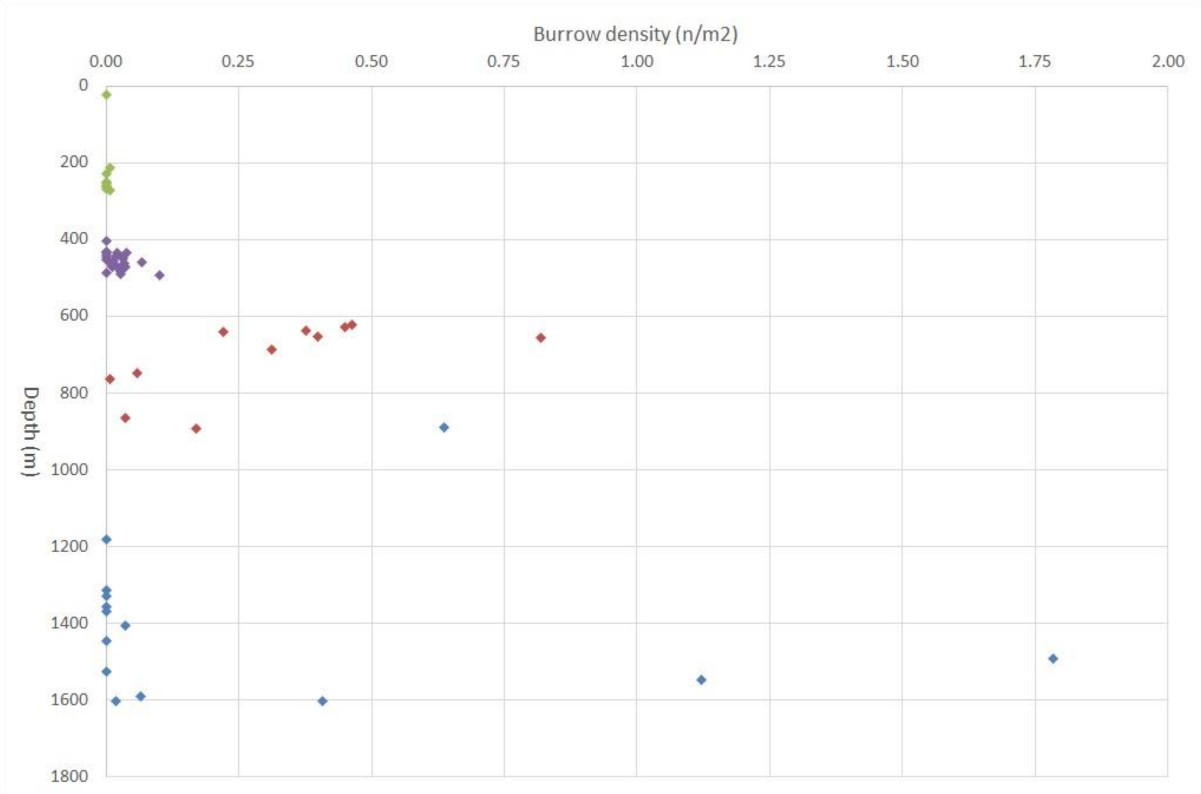

Figure 19: Burrow density (n/m^2) against depth (m). Colour indicates depth band: green = 200-400 m, purple = 400-600 m, red = 600-800 m and blue = >800 m.

When compared to the percentage of fine sediment (<0.063 mm) derived from video (Figure 20), the pattern is more challenging to unpick. While the station with the greatest percentage of fine sediment also has the greatest density of burrows, other stations across a range of boxes and percentages of fine sediment (typically <10%) display a variable burrow density. Shallower than depth of 600 m (purple and green points), burrow density is never greater than 0.25 burrows per m^2.

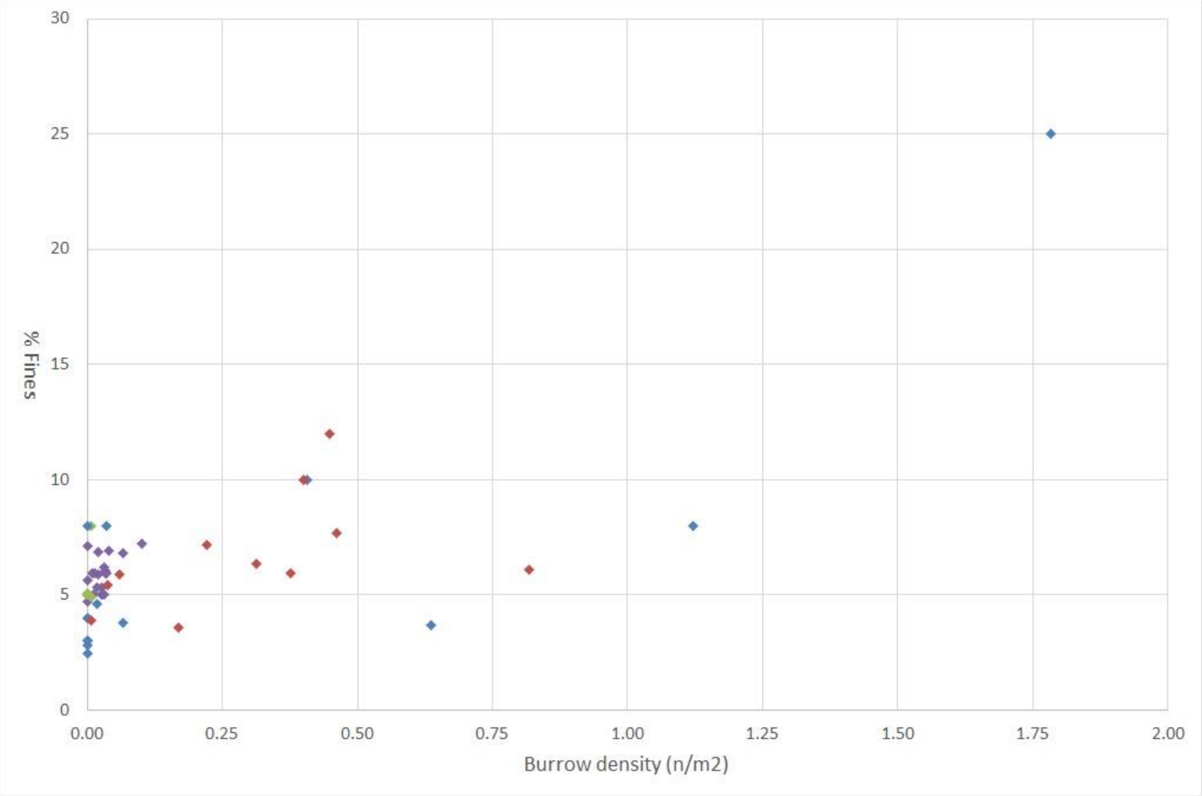

Figure 20: Burrow density (n/m^2) against % fine sediment (<0.063 mm) as derived from drop camera imagery. Colour indicates depth band: green = 200-400 m, purple = 400-600 m, red = 600-800 m and blue = >800 m.

3.3.5 Biotope classification

Given the small area of seabed observed in individual photographs, video data has been used to classify epifaunal biotopes from GSH.

Twelve habitat types / biotopes were identified from the 59 video tows (Figure 21). The majority of video tows were classified to Level 3 (i.e. to substratum type only), including 39 allocated to coarse sediments, eight allocated to sand habitat and a single tow classified as mud habitat (Detailed in Table 14).

The remaining 11 video tows were assigned a Level 4 (community level) biotope. Four video tows were assigned to the 'Urchin dominated community on Atlantic upper bathyal coarse sediment' (M.AtUB.Co.UrcCom) biotope, where *Cidaris cidaris* were recorded in high numbers, often alongside holothurians (*Parastichopus tremulus*). Three video tows were assigned to the 'Xenophyophore dominated community on Atlantic lower bathyal coarse sediment' (M.AtLB.Co.XenCom). Two video tows were assigned to the proposed new biotope 'Xenophyophore dominated community on Atlantic lower bathyal coarse sand' (M.AtLB.Sa[XenCom]) as this biotope currently only exists for coarse, muddy or mixed sediments. Another video tow was given a proposed biotope of M.AtUB.Co[Ditrupa] due to the presence of considerable numbers of *Ditrupa arietina* shells on coarse sediment. A final video tow was assigned to the 'Surface dwelling ophiuroid community on Atlantic lower bathyal mixed sediment' (M.AtLB.Mx.SurOph) biotope due to the presence of many large ophiuroids (possibly *Ophiomusa lymani*[6]) which were common.

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[6] Previously *Ophiomusium lymani*

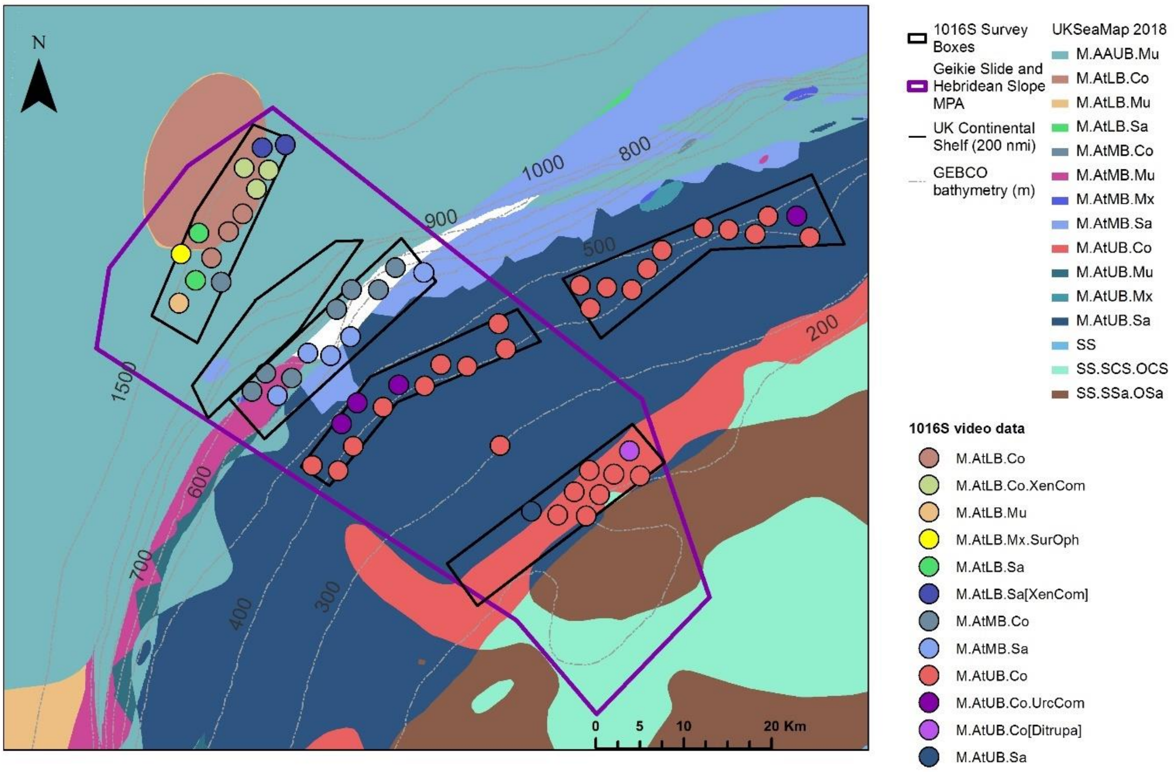

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Figure 21: Biotopes and habitats classified from 1016S drop camera video imagery using the Marine Habitat Classification for Britain and Ireland (MHC code).

Table 15: Habitat and biotope types identified or proposed from video analysis of GSH (Marine Habitat Classification for Britain and Ireland Classification v15.03)

Habitats and biotopes	Habitat & Biotope Codes	No. of video Segments
Atlantic lower bathyal coarse sediment	M.AtLB.Co	3
Xenophyophore dominated community on Atlantic lower bathyal coarse sediment	M.AtLB.Co.XenCom	3
Atlantic mid bathyal coarse sediment	M.AtMB.Co	8
Atlantic upper bathyal coarse sediment	M.AtUB.Co	28
(Proposed) *Ditrupa* dominated community on Atlantic upper bathyal coarse sediment	M.AtUB.Co[Ditrupa]	1
Urchin dominated community on Atlantic upper bathyal coarse sediment	M.AtUB.Co.UrcCom	4
Surface dwelling ophiuroid community on Atlantic lower bathyal mixed sediment	M.AtLB.Mx.SurOph	1
Atlantic lower bathyal sand	M.AtLB.Sa	2
(Proposed) Xenophyophore dominated community on Atlantic lower bathyal sand	M.AtLB.Sa[XenCom]	2

Atlantic mid bathyal sand	M.AtMB.Sa	5
Atlantic upper bathyal sand	M.AtUB.Sa	1
Atlantic lower bathyal mud	M.AtLB.Mu	1

3.4 Type 3 Monitoring study between Box D and Box F

3.4.1 Particle Size Analysis

Comparing PSA and imagery sediment classifications between Boxes D and F allows us to assess how similar the habitats present in each box are and thus how suitable they are for a BACI type study. Comparing habitat classification, more samples are classified as mixed sediment in Box F (4 out of 18) than Box D (1 out of 18) with the remainder of samples in Box F (14 out of 18) and Box D (17 out of 18) classified as mud. However, when comparing the relative amounts of gravel, sand and mud in each fraction (Figure 10), it is apparent that the variability within boxes is greater than any variability between boxes. This is especially true of mud and sand fractions which were found to co-vary, while the fraction of gravel remains well below 10% in the majority of samples. Furthermore, when considering imagery, samples from all video tows across all boxes are classified as coarse sediment. From stills, the majority of images in both boxes are classified as coarse, with a greater percentage of samples from Box F classified as sand (i.e. outside the MPA boundary, Figure 12). Overall, the disparity between classifications from corer samples and images within the MPA is also seen in Box F outside the MPA and is discussed in Section 4.4.1.

3.4.2 Infaunal community comparison

As described in section 3.2.2, the infaunal communities differ between Boxes D and F but the strength of that effect is weak (ANOSIM R=0.219, P <0.001, Table 8). This is also shown by nMDS ordination and CLUSTER analysis (Figure 15 and Figure 16). SIMPER reveals (Table 16) that dissimilarity is driven by variable abundances of a wide range of taxa, with no one taxon contributing more than 0.95% to overall dissimilarity between boxes. Notably, many taxa (138) contribute to 70% of the dissimilarity between boxes, further highlighting the complex picture and lack of strong individual drivers. Furthermore, when considered against the intra-box similarity for both Boxes D (51.76%) and F (53.26%), the inter-box similarity of 50.43% highlights that samples taken within boxes are almost as variable as samples between boxes. This is well represented visually in Figure 14, where the spread of samples both within and across Boxes D and F is evident.

Table 16: SIMPER analysis of top 5 contributors to dissimilarity between infaunal communities in Boxes D and F.

Taxa	**Box D mean abundance**	**Box F mean abundance**	**Mean dissimilarity**	**% Contribution to total dissimilarity**	**% Cumulative dissimilarity**
Copepoda spp.	1.13	0.63	0.48	0.97	0.97
Unciola planipes	0.37	1.22	0.45	0.92	1.89
Podocopida spp.	0.24	1.12	0.43	0.87	2.76
Parvicardium sp.	0.96	1.58	0.42	0.85	3.61
Spatangoida spp.	1.20	0.65	0.42	0.84	4.45

3.4.3 Epifaunal community comparison

Within epifaunal communities, described in section 3.3, there are several points of interest when comparing Boxes D and F. Firstly, nMDS results (Figure 17) reveal that samples from Boxes D and F overlap to some degree. When tested with ANOSIM, Boxes D and F were different, but in line with infaunal samples, the strength of that effect is the weakest observed (ANOSIM R=0.782, P <0.001, Table 12). In keeping with infaunal results, no one taxon controls dissimilarity between groups (Table 17). There are notably fewer taxa contributing to 70% dissimilarity between boxes (15), although this is likely a function of the higher-level taxonomic identification achievable from imagery relative to infauna (i.e. order level vs. genus/species level identifications).

Table 17: SIMPER analysis of top 5 contributors to dissimilarity between still imagery derived epifaunal communities in Boxes D and F.

Taxa	Box D mean abundance	Box F mean abundance	Mean dissimilarity	% Contribution to total dissimilarity	% Cumulative dissimilarity
Porifera spp.	0.58	0.08	3.44	7.94	7.94
Brachiopoda spp.	0.49	0.00	3.10	7.15	15.09
Cidaris cidaris	0.54	0.14	2.82	6.50	21.59
Parastichopus tremulus	0.46	0.09	2.57	5.93	27.52
Polychaeta spp.	0.22	0.47	2.57	5.34	32.86

3.5 Evaluation of the biological community zones model within GSH

The biological community zones model biotopes proposed by Hughes *et al.* (2014) were assigned to epifaunal community and sediment data derived from drop camera video transects (Figure 21). Infaunal biotopes are not considered in the evaluation of the Hughes *et al.* (2014) model as it is based on archived stills and thus epifauna only. Stills were not used as a single image does not cover sufficient seabed area for biotope assignment. Due to the issues described with video imagery and the poor taxonomic resolution of the data, the biotopes assigned are largely at a high level within the hierarchy (i.e. no community data). It should also be noted that while the model does integrate some data from the wider ‘Geikie bulge’, no data from within the current MPA boundary were used to inform the model. Where possible, the comparisons made are as follows:

- **Outer shelf and shelf break zone (135 - 227 m; Box E)** – This zone is characterised by a range of coarse sediments and epifauna such as *Cidaris cidaris* and asteroids. The results from video imagery collected in Box E largely agree with this; eight of the nine tows were classified as upper bathyal coarse sediment, one of which was dominated by large numbers of the tube-building annelid worm *Diturpa arietina*. One tow is classified as upper bathyal sand but the model and data are largely in agreement over the sediment types in Box E.

- **Upper slope zone (279 - 470 m; Boxes D and F)** – This zone is generally characterised by coarser sediments with sand and gravel patches and predominantly includes echinoderms as visible fauna. In Box D (and Box F outside the site boundary) the model and video biotopes largely agree. All tows were classified as coarse sediment and four of the tows were assigned to M.AtUB.Co.UrcCom, highlighting the importance of echinoids as the dominant fauna. It should also be noted that echinoids, asteroids, ophiuroids and holothurians make up over half of the fauna observed in video tows in both Boxes D (63.44%) and F (51.78%).

- ***Ophiocten gracilis* zone (600 – 1020 m; Box C)** – This biological zone is predicted to be dominated by large numbers of the small brittlestar *Ophiocten gracilis* on fine sandy, muddy sand or sandy mud, with some areas of gravel or cobbles. While the visual classification of sediments reflects this, with an increased number of samples classified as M.AtMB.Sa (5 out of 12; Box C), a lack of taxonomic detail makes evaluating the presence or absence of *Ophiocten gracilis* impossible. Notably, in Box A, a single tow has been assigned to the M.AtLB.Mx.SurOph biotope (Figure 21) indicating that surface ophiuroid biotopes persist into deeper water than predicted by the model. Additionally, the presence of the sister taxon to *Ophiocten gracilis*, *Ophiocten abyssicolum*, in Box C in box corer samples (total individuals=27) points to the presence of ecologically similar taxa, accepting that *O. abyssicolum* was found to be much more abundant in the shallower Boxes D and F (total individuals=145 and 162 respectively).

- **Xenophyophore zone (1088 - 1180 m; No samples)** – a biological zone characterised by the xenophyophore *Syringammina fragilissima* in rippled muddy sand or sandy mud. While no samples were taken in this narrow depth band, the presence of xenophyophores is discussed below.

- **Decapod burrowing zone (1293 - 1595 m; Box A)** – The deepest modelled zone is characterised by the burrows of large decapods such as *Munida tenuimana* in fine muds. However, in the imagery from Box A, a range of disparate biotopes have been recorded, ranging from coarse sediment (M.AtLB.Co) to mixed sediments (M.AtLB.Co.Mx.SurOph) to sand (M.AtLB.Sa) to mud (M.AtLB.Mu). In addition, communities of surface ophiuroids and xenophyophores on both coarse sediment and sand have been described. Whilst several stations in box A have notably high numbers of burrows (Fig. 18.), there are also a number of stations without burrows. It appears that xenophyophores persist into deeper waters than modelled and that surface sediments are more heterogenous in the deepest areas of GSH than previously predicted.

3.6 Other priority marine features (PMFs)

No undesignated benthic PMFs were detected during the analysis of data from GSH.

Some mobile (e.g. *Lophius piscatorius*) and limited mobility benthic (e.g. *Pachycerianthus sp.*, *Nephrops norvegicus, Geodia nodastrella*) species of interest were present, and others cannot be excluded (e.g. high-level identifications of Scleracatinia could be *Lophelia pertusa* or Pleuronectiformes could be examples of *Hippoglossus hippoglossus* or *Reinhardtius hippoglossoides*).

3.7 Non-indigenous species

No non-indigenous species were detected during the analysis of data from GSH.

3.8 Marine litter and anthropogenic impacts

The presence of marine litter and anthropogenic impacts are detailed in cores/incidentally (Table 19, Figure 22) and from imagery data (Table 18, Figure 22).

At one station (BoxC_C03_S18) possible evidence of bottom contact fishing gear could be seen, where disturbed, broken clumps of muddy sand were observed in lines. These features were also seen at the end of BoxC_C01_S20 but were not as linear and thus were not recorded as evidence of mobile fishing gear.

Table 18: Anthropogenic impacts and litter observed in drop-frame imagery.

Video tow	Time	Anthropogenic impacts / litter
BoxC_C03_S18	Throughout	Possible trawl marks
BoxA_A03_S78	00:35	Uncertain (plastic)
BoxA_A05_S79	02:42	Uncertain (green objects)
BoxC_C03_S18	08:38	Possible rope
BoxC_C04_S19	10:54	Possible rope
BoxC_C11_S05	01:29	Glass
BoxD_D03_S22	06:42	Possible rope
BoxD_D09_S30	07:28	Possible metal spring/cable

Additionally, anthropogenic impacts and litter were observed in core samples and entangled around the chariot frame.

Table 19: Anthropogenic impacts and litter observed in core samples and on sampling gear.

Sample	Date / time	Anthropogenic impacts / litter
C06	23/07/16 05:49:30	Pottery in core sample
F17	31/07/16 06:02:22	Monofilament in core sample
Tow_02 (Chariot)	01/08/16 14:25:00	Rope entangled on chariot frame

4 Discussion

From the dataset collected during MRV Scotia cruise 1016S (O'Connor *et al.* 2016), it is evident that there is a globally complex picture of the designated features within GSH. In summary:

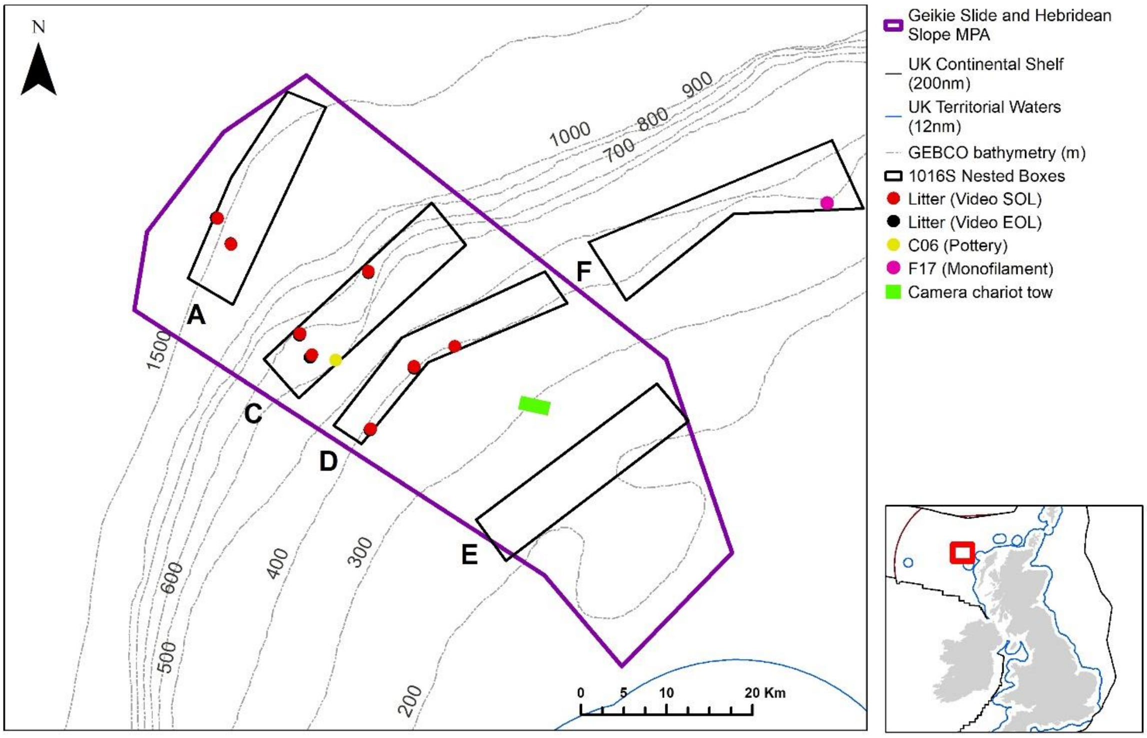

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Figure 22: Marine litter at GSH. Red and black dots represent start and end of video tows respectively, yellow dots represent core samples, and the green strip represents the chariot tow.

4.1 Site level summary

- Mud is much more widespread within the site than previously predicted but co-exists under a widespread layer of coarser sediments, primarily sands. However, this is likely to be a result of sampling a deeper horizon (0-15 cm) than previous work in the area (e.g. Bett 2001 (0-5 cm) and (0-2 cm)).
- The infauna present within GSH are structured along the significant depth gradient at the site.
- Epifauna are present in densities ranging from 1.68-6.43 individuals/m^2 and the resultant data set is structured by presence/absence of taxa. However, the drop camera imagery provides only a coarse taxonomic resolution.

4.2 Offshore deep-sea muds and burrowed mud

For monitoring purposes, the designated features of offshore deep-sea muds and burrowed mud will be considered together.

4.2.1 Extent and distribution

While deep-sea muds were previously thought to be confined to the deepest areas of the site in a mosaic with muddy sand (Figure 1), PSA results from core samples appear to show this feature to be much more widespread. The majority (49 of 56) of samples across all boxes were classed as mud, superficially suggesting the feature is more widespread than previously predicted (Figure 8).

However, the imagery data derived from both drop camera and chariot tows largely disagree with this interpretation. Accepting the difficulties of visually classifying sediments (Durden *et al.* 2016) and the variable image quality, this clear disparity between the physical samples and imagery (Figure 8 and Figure 11) warrants investigation. Given that the imagery covers a much greater area of the site than the point samples provided by the cores, it seems counter intuitive that large tracts of the seabed are classified as sand and coarse material, yet by chance, small, discrete areas of mud have been targeted by the box corer and not observed in camera transects at the same station.

The answer lies in the selection of a box corer as the primary sampling gear and the subsampling of a 15 cm horizon. The USNEL corer used is designed to penetrate soft sediments to a depth of approximately 65 cm and during this survey, the corer penetrated on average 35 cm into the sediment (max. 60 cm, min. 20 cm). As such, it is probable that the greater proportions of coarse sediments and sands observed in imagery exist as a surficial horizon or veneer across the site and that underlying mud is dominant in the cross section at greater horizon depths than sampled in previous studies (e.g. Bett 2001). This concept is supported by field notes and photographs (Appendix 9), where 40 of the 56 (71.43%) core samples were noted as having a sand layer overlying mud, a phenomenon evident in the core subsample reference images (Appendix 8).

With this in mind, understanding the extent and distribution of offshore deep-sea muds becomes complex. From the surveyed boxes, PSA results show that mud is present throughout the site (and outside the site boundary in Box F), although it is not necessarily present in isolation from other sediment types and in some samples may exists solely in deep sediment horizons beyond which the majority of fauna are found. This also explains the disparity between modelled data and PSA results, with the former being produced largely from more surficial samples.

In any case, offshore deep-sea muds may cover a much greater extent than previously predicted and are distributed from shallow waters down the continental slope and into deeper water, depending on how the relationship between coarser surface sediment and deeper cores is resolved through PMF description.

In addition, the PMF burrowed mud can be evaluated across GSH. Accepting the evidence for a surficial horizon of coarser sediments over mud and the widespread presence of mud throughout the site, we can interpret suitable sediment to be widespread. Turning to the presence of burrowing megafauna (Section 3.3.4), it is clear that there is an increase in burrow density with depth (Figure 15). Notably, burrows are widespread in Box C (600-800 m) in densities of 0.26 - 1.00 per m^2. Within the deepest box sampled, Box A (>800 m), there are two stations with greater burrow densities than the rest of the site (> 1 burrow/m^2) but also seven stations where burrows are absent. In Boxes D, E and F (<600 m) there is a similar pattern of several stations with low burrow densities (<0.25 burrows/m^2) and several stations without burrows. Given the widespread presence of apparently suitable burrowing substratum throughout the site it is unclear as to what drives the observed distribution of densities, especially the stations in Box A that lack burrows altogether. Possible reasons behind this distribution include small scale substratum suitability, such as thicker veneer or mud that is too consolidated to burrow into, predation, localised anthropogenic pressure or natural variability. Additionally, it is important to note that the data does not address the nature of the burrows and while the abundance may be greater in deeper areas of the site, this does not point to the presence/absence of larger/more complex burrows and as such it is unclear as to what fauna are driving the observed variability in burrow distribution.

As such it is pertinent to consider the PMF at site level, where it appears widespread although it should be noted that the absolute number of burrows present at GSH is low throughout. The use of additional data, such as landings of *Nephrops* from the area, may provide additional insight that cannot be provided by imagery alone. Additionally, a lack of specific criteria for the classification of burrowed mud makes establishing the true extent of this feature challenging. In broad terms, the widespread distribution of mud and presence of burrows means that this PMF is widely distributed throughout the deeper areas of the site. Future assessment of what constitutes sufficient density of burrows for the PMF in future would be useful in assessing the feature attributes (namely extent, distribution and structure).

4.2.2 Physical structure

When assessing physical structure, as discussed above, the presence of coarser (>0.063 mm) sediment veneers is important in describing the physical structure of sediments at GSH. Across all survey boxes, there is evidence of stratification in the sediment, with a layer of coarser sediment (primarily sand) overlaying a deeper layer of mud.

The collection methodology is a significant factor in this result. The use of a box corer allows for the collection of a complete undisturbed sediment sample that cuts deeper into the sediment than other commonly used physical sampling gears. When sub-sampled for PSA, a sub-core was taken using an acrylic pipe to extract a 15 cm section, much deeper than used in previous studies in the wider area (e.g. Bett 2001). This is typified in the points from British Geological Survey (BGS) data which was collected from surficial Shipek Grabs or gravity cores (Figure 3). As such, detailed examination of the physical structure of sediments at GSH is unlikely to yield comparable results to past work based on a 0-15 cm horizon.

Furthermore, whilst field notes and photographs are available, the characteristics they describe (e.g. colour, odour, conspicuous fauna) are largely consistent throughout the site and add limited value to the interpretation. In future, the use of quantified parameters, such as total organic carbon or other sediment chemistry metrics, may provide more robust information to support field observations of layering and physical characteristics.

4.2.3 Biological structure

Assessing biological structure within deep-sea mud features at GSH is complex for three reasons: sediment veneering, the presence of a ‘long’ ecological gradient (water depth) and disparity between infaunal and epifaunal community patterns.

Firstly, the presence of extensive sediment veneers and the resultant disparity between imagery and PSD habitat classification means that the habitats are somewhat partitioned, with a surface sand-based epifauna, and a sub-surface mud-based infauna. The former is addressed in Section 4.3, however the latter presents further complexity as the observed patterns (Figure 17) are overwhelmingly driven by depth (which may be acting as a proxy for environmental conditions, such as temperature, sediment type, nutrient supply or a combination thereof), as shown by BEST analysis (Rho=0.885). The addition of sediment type to the BEST analysis explains less of the variation than depth alone, although this is potentially an artefact of the collection of a deeper 15 cm horizon than in previous work.

Therefore, as the majority of core samples are classified as mud using a 15 cm horizon, it is pertinent to examine changes in community with depth. The significant separation between boxes across the depth gradient (ANOSIM R = 0.607, P<0.001) and the weakness of that separation between Boxes D and F (R = 0.225, P<0.001), supported by BEST analysis, clearly shows that depth is the primary driver of variation. Notably, the shallowest box (Box

E) is the most distinct, whilst Box D (on the continental slope) and Box C (at the base of the slope) show poorer separation (Figure 17).

This poorer separation may be explained by the presence of numerous deep-sea specific taxa in Boxes C and D (and outside the site in Box F). As noted in the analysis report (Chamberlain *et al.* 2017), while the overall assemblage is dominated by polychaetes, especially *Glycera spp.*, there are numerous deep-sea specific taxa, many of which are found in Boxes C and D (and outside the boundary in Box F). Firstly, many infrequently recorded deep-sea polychaete species were found at GSH, including *Eusthenelais hibernica, Paranaitis* cf. *uschakovi, Linopherus hemuli, Samythella elongata, Pseudexogone dineti,* Syllidae such as *Parexogone longicirris* and *Exogone sorbei,* and Paraonidae such as *Levinsenia flava, L. kantaurensis* and *Paradoneis mikeli*. These were found both within the site and in Box F outside the site boundary. Secondly, Crustacea were notably diverse within the survey area; several crustaceans, such as *Styloptocuma gracillimum, Platysympus typicus* and *Makrokylindrus josephinae,* were recorded in Box C and isopods typical of deeper water were recorded from Boxes C, D and F. The deep-water decapods *Dorhynchus thomsoni* and *Cymonomus granulatus* were recorded in Box C and Box D, respectively. In addition to infrequently recorded polychaetes and crustaceans, several deep-sea ophiuroids (*Ophiacantha abyssicola, Ophiocten abyssicolum and Dictenophiura carnea*) and deep-sea Nuculanidae were present in Boxes C, D and F. Deep-sea gastropods *Amphissa acutecostata* were also present in Boxes C and D.

Overall, this survey has collected a wide range of deep-sea fauna from numerous phyla. Whilst it is not unexpected to collect deep-sea fauna from a deep-sea MPA, this dataset forms an important point in monitoring the biological structure and function of fauna at GSH and across the wider Hebridean slope.

Many characteristic fauna of the burrowed mud PMF were not present during the analysis. While some examples, such as seapens, cerianthid anemones and burrowing megafauna (e.g. *Nephrops norvegicus*) are poorly represented in cores and better represented in imagery (see below), others are not. Only two individuals of *Callianassa subterranea* were recorded (from Box E) and no other mud shrimps (e.g. *Calocaris macandreae*) or burrowing amphipods (e.g. *Maera loveni*) were recorded, although it is challenging to establish baseline densities for many of these fauna in a pristine site. Additionally, no echiurans (e.g. *Maxmuelleria lankesteri*) were recorded. Despite the lack of characterising fauna in the samples collected form GSH, it should be noted that the burrowed mud PMF in the deep-sea is poorly described.

Using imagery provides useful insight into the biological structure of mud features, despite the extensive sediment veneering. Given that imagery covers a wider area than coring, it provides insight into spatially discrete species and burrows, both of which are critical to the burrowed mud PMF. Notably, the density of burrows increases with depth where burrows are not absent (i.e. all depth bands have stations where burrows are absent (Figure 18 and Figure 19), which would suggest improved conditions for burrowing megafauna. This could include factors such as more stable water conditions, greater availability of fine material to burrow into or increased food availability. However, when examining any reason behind this observed change it should be noted that the absolute abundance of burrows at GSH is low in all cases. While this survey does not attempt to quantify why these patterns are evident, it would be pertinent for future work to examine the drivers behind changing abundances of burrows within MPAs. The increase in abundance of *Nephrops* burrows with depth, as typified by their presence in 75% of stations in Box C, again points to improved conditions for burrowing megafauna with depth, especially when considered in tandem with the mixture of other large and small burrow openings at many more of the sites. While seapens were not observed at any of the sampling stations, the presence of abundant burrows may point to a complex and rich sub-surface ecology.

4.3 Offshore subtidal sands and gravels

4.3.1 Extent and distribution

Sands, and to a lesser extent gravels, are a significant feature at GSH, especially in surface sediments. The sediment classifications from imagery (both video and stills) (**Figure 11**) point to wider distribution of the feature in the surface sediments in the deepest parts of the site. The disparity between the substrate classifications from box corer samples and imagery data indicate that the use of a single habitat description (mud, sand, coarse or mixed sediment) is a poor descriptor of the layering evident from field notes and underestimates the prevalence of sands and gravels across the site.

4.3.2 Physical structure

Physical structure of sands and gravels at GSH is dominated by veneering. This may have implications for the faunal assemblage observed, with an epifaunal community living on sand, while the infaunal community lives in mud. This should be borne in mind when examining the condition of PMFs as there is no clear separation between mud and sands/gravels, especially over the 15 cm horizon examined. This is further exemplified in the habitat classification, where small changes in the proportion of muds to coarser material result in some cores being classified as mud, while others of similar composition are classified as mixed sediments, most notably outside the site boundary in Box F (Figure 10).

Overall, the physical structure of offshore subtidal sands and gravels within GSH is primarily that of a veneer over an underlying layer of mud. Future assessment of the condition of these PMFs should carefully consider the implications of this structure and the depth of sediment horizon examined.

4.3.3 Biological structure

Within this feature, the samples classified as mixed sediment are largely similar to mud samples within the same box, with small changes in the relative proportions of coarse material affecting habitat classification (Figure 9). BEST analysis has shown that the addition of additional factors, such as sediment type (expressed as percentage coarse, sand or fine sediment), explains less of the variation than depth alone. This is due to the much greater gradient of depth relative to a much smaller gradient of sediment type, and that this gradient does not correspond to any spatial feature.

More broadly, when considering the epifauna present on sands and gravels at GSH there is limited structure in the data and high variability. Given the high taxonomic level of many identifications and the large intra box variability, this is unsurprising. The presence/absence structure of the data is also a significant factor and given the known spatial heterogeneity of deep-sea fauna (Ramirez-Llodra *et al.* 2010; Jones *et al.* 2013), like that at GSH, it is possible that larger sample areas should be considered in future. The use of alternative sampling gears to sample fauna from this feature, such as sledges and trawls, may also be worth consideration in future, noting their inherent drawbacks.

One point of note is the presence of xenophyophores, primarily *Syringammina fragilissima*, in Box A and their absence elsewhere. This is the greatest faunal driver of dissimilarity between the epifaunal communities in Box A and elsewhere (contributor to dissimilarity between Box A and Box: C=10.71, D=9.39%, E=12.48%) and points to a deeper distribution of xenophyophores than predicted from the Hughes *et al.* (2014) model, accepting that the Hughes model does not utilise all available data from the region and that xenophyophores have been observed in wider depth ranges in other studies (Bett 2001).

4.4 Comparison of Boxes D and F

Based on prior selection due analogous depth, predicted habitat and fishing pressure, Boxes D and F were predicted to be suitable areas to represent the 'before' and 'control' sites of a BACI study. Using the data from this survey we can further evaluate if the sites are truly comparable based on PSA, infaunal communities and epifaunal communities.

4.4.1 Particle size distribution (PSD)

PSD results (Section 3.1.1) show that while there are more samples classified as mixed sediment in Box F than Box D, the variability of sediments within boxes is greater than variability between boxes (Figure 12). Furthermore, imagery results show that from drop frame video (i.e. the broadest classification across wider areas than stills imagery or cores) all samples are classified as coarse sediments. In still imagery, there are a greater number of samples classified as sand in Box F, especially in the west of the box, but considering the difficulties in identifying sediments from imagery and the small spatial scale covered by each image, it is unlikely that this represents large scale variability in sediment across the boxes. The presence of veneered sediment is also evident in both boxes and there are no significant changes in substrate.

4.4.2 Infaunal community

Infaunal communities within both boxes have been shown to be largely analogous. From descriptive statistics (Table 6) we can see a similar number of average fauna across cores were collected, when considered with standard deviation, and there are similar numbers of species, very similar richness and very similar evenness within both boxes. Within nMDS ordination (Figure 14) the samples are shown to be closely ordinated and while pairwise ANOSIM testing has shown that samples from the boxes are statistically distinct, the strength of this effect ($R = 0.225$, $P<0.001$) is weak. Furthermore, clustering (Figure 15) has shown that the majority of samples in Boxes D and F are freely permutable below a similarity of 50%. It is also pertinent to consider the low intra-box similarity in both boxes (D=52.36, F=53.51) when considering inter-box similarity (i.e. samples in a box are nearly as variable as samples between boxes). Overall, while the boxes are statistically distinct, it is likely that they represent the same broad community continuum.

4.4.3 Epifaunal community

The epifaunal communities show similar patterns across Boxes D and F. Considering still imagery, descriptive statistics appear broadly similar across boxes (Table 11). Faunal density is very similar (Box D 6.36 ± 3.03, Box F = 6.43 ± 1.16) and while diversity and evenness metrics are somewhat different (Table 11), this should be considered in the wider context of the data, especially spatial patchiness. The use of other sampling methods, such as trawls, may be able to account for some of this patchiness across the boxes, although care must be taken when using such sampling gear that the conservation objectives can still be met. Comparing community composition, nMDS highlights the moderate intra-box and low inter-box variability (Figure 17) however pairwise ANOSIM testing shows that Boxes D and F are distinct (stills, $R=0.782$, $P<0.0001$). SIMPER analysis also reveals that similarity within boxes is low (Table 13). In summary, while there are some metrics derived from still imagery that vary between boxes (e.g. abundance), there is low similarity within boxes, coupled with weak separation between boxes in both epifauna and infauna, and strong PSA resemblances and visual sediment classification between the boxes.

Additionally, the use of Boxes D and F in a BACI design is also dependent on the abatement and continuation of pressures inside and outside the site respectively. Future assessment of the boxes should make best possible use of up-to-date fishing pressure data to ensure comparability across time.

In conclusion, Boxes D and F are suitable sites for monitoring the efficacy of fisheries management measures within the Geikie Slide and Hebridean slope MPA as part of a BACI study, however the use of a 0-15 cm horizon will have implications for examining future change in the site.

4.5 Evaluation of the biological community zones model within GSH

Comparing and contrasting the model produced by Hughes *et al.* (2014) with biotope imagery data from this survey allows us to evaluate how accurate it is within GSH and look at potentially updating the model for future use in offshore Scottish waters.

Examining the shallowest sampled box, Box E, which is predicted to fall within the outer shelf and shelf break zone, reveals some patterns of interest. Sediment classifications are broadly consistent with the model, albeit at a low resolution (coarse, sand, mixed sediment, etc.). The zone is also predicted to have sparse epifauna dominated by echinoderms, especially asteroidea and urchins such as *Cidaris cidaris*. While no *Cidaris cidaris* specimens were found in this survey in Box E, there were echinoid specimens that could not be assigned to a species. Notably, Box E contained fewer echinoderms than boxes C and D.

The predicted *Ophiocten gracilis* zone between 600 and 1020 m (Figure 21, red band) is also difficult to classify. While sediment descriptions again are broadly consistent, the characterising species (*Ophiocten gracilis*) cannot be identified below genus level from imagery due to the keys used (Chamberlain *et al.* 2017). However, the presence of deep-sea ophiuroids, such as *Ophiacantha abyssicola*, *Ophiocten abyssicolum* and *Dictenophiura carnea*, in box corer samples collected from Boxes C, D and F may point to a more ophiuroid dominated community than suggested by imagery, even if the characterising species (*Ophiocten gracilis*) was not found during this survey.

Samples collected from Boxes D and F fall mainly within the ‘upper slope zone’, which is predicted to have sparse visible fauna, but those present will mainly be echinoderms such as *Spatangus raschi, Gracilechinus* sp. and the Holothurian *Parastichopus tremulus*[7] (Hughes *et al.* 2014). In both Boxes D and F, over half the fauna observed in video tows were echinoderms (63.44%, 51.78% respectively) and, despite the poor taxonomic resolution achieved, this pattern of epifaunal echinoderm dominance is clear. In addition, the classification of four tows as M.At.UB.Co.UrcCom highlights the importance of epifaunal echinoids in these boxes, supporting the outputs of the model.

Within Box A however, the results from the model and observed data diverge. While the model predicts burrowing decapods on fine muds, the results from video are varied and include four sediment types (mixed, sand, coarse and mud). Notwithstanding the difficulties in classifying sediments from imagery and the presence of sediment veneers described above, it would appear that coarser material persists further down the continental slope than predicted by the model. In addition, the presence of burrows is correlated with the mud classification in the south of Box A (Figure 18), which points to the presence of burrowing megafauna in the box as well as other biotopes. Most notably, the description of five tows as xenophyophore dominated biotopes in the north of Box A (Figure 21) shows that xenophyophores are present in deeper water than predicted by the model. It appears that the predicted area for xenophyophores in the model is too narrow and, as shown from this survey, they exist and even dominate over a greater depth range than predicted by the

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[7] Previously *Stichopus tremulus*

Hughes model (as previously established (Bett 2001)). So, while the presence of burrowing decapods in fine mud is not entirely ruled out, the biotopes found in Box A show much greater diversity and spatial complexity than previously assumed. This development of understanding should be used to inform future monitoring of GSH and other MPAs that cross similar depth profiles where our understanding of faunal distribution patterns is rudimentary.

4.6 Biotope classification

The assignment of infaunal biotopes within GSH is difficult for several reasons: firstly, the strong depth gradient present at GSH means that there is a transition from offshore sediments to upper, mid and lower bathyal sediments, the latter three of which have poorly described infaunal level biotopes. Secondly, the specific nature of existing biotopes means that while many of the characterising species were found in corer samples, the absence of others makes assigning existing biotopes inappropriate. Thirdly, the presence of veneered sediment and the depth to which a box corer can penetrate and be sampled from may affect the subsequent fauna retained, and therefore the final biotope classification.

Within epifaunal biotopes, the availability of more community level biotopes is notable, but other concerns are present: while the use of video over still imagery allows us to assess biotopes over spatially appropriate scales, the spatially patchy nature of deep-sea epifauna often hinders attempts to biotope a section of video, especially given the lack of numerical criteria for designating biotopes (i.e. how many individuals of a characterising taxon are required to classify a level 5 biotope). Furthermore, discriminating sediment type from imagery accurately and consistently is challenging, especially given the difficulties of maintaining altitude above the seabed and water clarity, and lacks the objectivity of physical samples.

Within infaunal samples, the presence of many infrequently recorded deep-sea specific taxa is notable, and the classification of the Level 4 community ‘Mixed infauna dominated by polychaetes’ captures both the diversity of infauna and dominance of polychaetes. This biotope is described for sand and mud in a range of depth bands relevant for GSH (Atlantic upper and lower bathyal sand, Atlantic mid and lower bathyal mud) and thus is appropriate for wide areas of the site

Overall, the classification of Level 3 biotopes (i.e. to substratum type only) from both imagery and physical samples is a straightforward and useful tool to help describe the extent and distribution of PMFs within the site at large.

Considered holistically, it is apparent that there is a disparity between the classification of infaunal and epifaunal communities. The greater number of described epifaunal biotopes compared to infaunal biotopes makes it challenging to draw equivalent comparisons across GSH. Future studies within the transitional area from shelf sea to continental slope and deep sea should seek to improve the classification of deep-sea infaunal biotopes or examine how epifaunal biotopes can be used in isolation.

4.7 Presence of undesignated priority marine features (PMFs)

Although some mobile (e.g. *Lophius piscatorius*) and limited mobility benthic (e.g. *Pachycerianthus sp.*, *Nephrops norvegicus, Geodia nodastrella*) species of interest were found, it is unlikely that these scarce observations constitute nationally or internationally significant populations, especially given their wide distribution within Scottish offshore waters and within the wider NE Atlantic.

4.8 Non-indigenous species

No non-indigenous species were detected during the analysis of data from GSH. However, it should be noted that the list cross references (Appendix 3) are primarily aimed at shallow water and estuarine taxa. The lack of a suitable deep-sea specific non-indigenous species list and a poor understanding of the native range of many species, both spatially and with depth, makes assessing the distribution of non-indigenous species within deep-sea sites extremely challenging.

4.9 Marine litter and anthropogenic impacts

As detailed in Section 3.8, there are several instances of litter and evidence of anthropogenic impact within GSH. Two of the instances of litter physically retrieved and several of the observations in imagery are likely linked to fishing activity, namely monofilament line and rope, while other instances of general litter such as pottery or glass may be from a range of sources. Compared spatially, all instances of litter were observed in the deeper Boxes D, C and A.

The presence of possible trawl marks is not unsurprising, given known fishing activity in the area.

5 Recommendations for future monitoring

In light of the completion of the first UK deep-sea monitoring survey, the following recommendations for future monitoring in Geikie Slide and Hebridean Slope MPA and other deep-sea sites can be put forward:

5.1 Geikie Slide & Hebridean Slope

5.1.1 Operational and survey strategy

1. Use of a 0.5 mm sieve has been shown to display the same overall community patterns as the 0.25 mm sieve (Appendix 11). As such, the use of a 0.25 mm sieve at GSH has been shown to be superfluous and adds additional cost and labour for limited additional gain. Unless there is strong pre-existing rationale for using finer sieve meshes (Gage *et al*. 2002; Danovaro 2009; Philips *et al*. 2014), the use of a 0.5 mm sieve will be sufficient for future monitoring at GSH.
2. Collection of Chariot imagery has added limited value to the monitoring of GSH. If chariot imagery is to be used in future, it should be carefully considered as to what question it will answer.
3. The use of a 15 cm sediment horizon for PSA and infaunal samples has implications for the description of the feature attributes, comparison to past studies and investigating change in future. A narrower horizon may increase comparability with other studies in the area (e.g. Bett 2001) and reduce sample collection effort.

5.1.2 Analysis and interpretation

1. Within GSH and potentially in the wider region, the complex nature of veneered sediment must be interpreted with care, especially when considering the disparity in results between imagery and physical samples. Datasets collected from other sources with other sampling gears (such as gravity or vibrocorers) should be considered with caution to understand and monitor the full picture of PMF extent, distribution and structure within GSH and the wider MPA network.
2. Future description of PMFs should make best use of available data, especially where veneered sediments are evident and PMFs have been shown to co-exist spatially.
3. The use of operational taxonomic units (OTUs) or a global standardised marine taxon reference image database (e.g. SMarTaR-ID) would greatly improve the overall epifaunal dataset at this site, significantly reducing the inconsistencies and uncertainties between analysts (Howell *et al.* 2019).

5.2 Recommendations for future monitoring of the wider MPA network

5.2.1 Operational and survey strategy

1. When using box cores, it is sensible to either limit the sediment processed or increase sieving capacity.
2. Mechanical damage to infaunal taxa (especially those from the deep sea) has been highlighted as a significant impediment to identifying taxa to genus and species level. Future protocols should investigate the use of elutriation or other methods, such as a modified sieving table, as well as educating scientists of the importance of extracting soft bodied organisms in as good a condition as possible. Additionally, immediate sample preservation may be a viable alternative to reduce damage to fragile infauna (Degraer *et al.* 2007).

3. The collection of added-value sediment characteristics (Section 4.2.2) in future will improve understanding of the physical structure and function of PMFs.
4. The use of a boxed survey design has been shown to be an effective way to sample a large MPA with a known pre-existing environmental gradient (depth) with limited pre-existing data. Surveys to similar offshore MPAs should consider the benefits of a boxed survey design against other designs, such as a gridded survey.

5.2.2 Analysis and interpretation

1. Evaluating the biological community zones model (Hughes *et al.* 2014) will require targeted examination of community level biotopes from detailed imagery. However, while the model provides insight into the site in the absence of other data, collecting further data to ground truth the model will add limited value to the MPA monitoring programme more widely.
2. The lack of deep-sea specific infaunal biotopes precludes best utilisation of the dataset collected from GSH. In conjunction with future deep-sea surveys, the deep-sea section of the Britain and Ireland habitat classification should be further developed, especially to better represent infaunal biotopes.
3. Development of a deep-sea specific non-indigenous species list would assist scientists in evaluating the current and future spread of these species in the deep sea, accepting however the understanding of deep-sea taxonomy and biogeography is insufficient at this time to facilitate such a list.

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Appendix 1. Infauna analysis report

Available in supplementary materials:

1016S Survey Geikie Slide and the Hebridean Slope Scottish Nature Conservation Marine Protected Area Benthic Infaunal Sample Analysis. Thomson Unicomarine.
(JNCC-MSS-Report-2-Appendix-1)

Appendix 2. Epifauna analysis report

Available in supplementary materials:

Epibenthic Imagery Analysis for 1016S Survey of Geikie Slide and the Hebridean Slope Nature Conservation MPA. Envision Mapping Ltd.
(JNCC-MSS-Report-2-Appendix-2)

Appendix 3. Non-indigenous species (NIS) lists

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		

Appendix 4. Marine litter categories

Categories and sub-categories of litter items for seafloor 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*5 cm = 25 cm^2
B: ≤ 10*10 cm = 100 cm^2
C: ≤ 20*20 cm = 400 cm^2
D: ≤ 50*50 cm = 2500 cm^2
E: ≤ 100*100 cm = 10000 cm^2
F: ≥ 100*100 cm = 10000 cm^2

Appendix 5. Infaunal data truncation protocol

Raw taxon abundance and biomass matrices can contain entries that include the same taxa recorded differently, erroneously or differentiated according to unorthodox, subjective criteria. Therefore, ahead of analysis, the dataset was checked and truncated to ensure that each row represents a legitimate taxon.

Details of the data preparation and taxon exclusion protocols applied to the GSH infaunal datasets pre-analysis are provided below:

- Where there are records of one named species together with records of members of the same genus (i.e. the latter not identified to species level) the entries are merged to genus level (e.g. records of *Lepidasthenia sp.* and *Lepidasthenia brunnea* are merged to *Lepidasthenia sp.*).
- Where there are records of multiple named species together with records of members of the same genus (i.e. the latter not identified to species level) the entries are retained at species level to retain the detail of multiple species of the same genera as well as genus level identification, possibly due to damage to the specimen, rather than uncertainty in the identification (i.e. records of *Glycera spp.* and *Glycera alba, Glycera capitate and Glycera lapidum* are retained *as-is*).

Where taxa have to be merged to a higher taxonomic level than they were originally identified at, a compromise was reached between the information lost by discarding recorded detail on a taxon's identity and the potential for error in subsequent analysis if spurious entries were retained.

For records of juvenile individuals:

- If 'juvenile' records were recorded at the same taxonomic level as 'adult' records then the two records were combined
- If juveniles were recorded at a higher taxonomic level than adults then the 'juvenile' records were removed to avoid having to reduce the taxonomic resolution of the 'adult' records.
- Records of 'eggs' were removed

In addition, records of *Vertebrata spp.* and *Cephalopoda spp.* were removed.

Excluded taxa:

N.B. A '?' Qualifier indicates an uncertain identification, usually in poor quality imagery or an identification of a partial specimen.

Animalia
Animalia (eggs)
Aphroditidae (juv.)
Exogoninae (?)
Tharyx
Crustacea (larva)
Podocopida (?)
Nototropis guttatus (?)
Caecognathia elongata (?)
Epicaridea (larva)
Campecopea (?)
Decapoda (damaged)

Anapagurus laevis (eggs)
Cymonomus granulatus (eggs)
Geryon (?)
Insecta
Insecta (larva)
Propilidium exiguum (?)
Acteon tornatilis (juv.)
Fenestrulina (?)
Actinopterygii (eggs)
Molva molva (?)
Cliophora
Nemertrea
Nematoda
Entoprocta

Appendix 6. Epifaunal data truncation protocol

As described in Appendix 5, taxon exclusion serves to remove spurious entries and ensure the dataset being analysed is as robust as possible and an accurate representation of the faunal communities observed. Due to the nature of the imagery identification at GSH, a large number of identifications were made at a high taxonomic level with very high certainty. As such, the taxon exclusion carried out on epifaunal datasets was minimal.

Details of the data preparation and taxon exclusion protocols applied to the GSH epifaunal datasets pre-analysis are provided below:

- Records of *Vertebrata spp.* and *Cephalopoda spp.*
- Records of ‘eggs’ were removed
- Unidentifiable fauna (e.g. Species B, unidentified faunal turf) were removed

Excluded taxa:
N.B. A ‘?’ Qualifier indicates an uncertain identification, usually in poor quality imagery or an identification of a partial specimen.

Actinopterygii
Actinopterygii Aldrovandria phalaca?
Actinopterygii Clupeidae
Actinopterygii Lepidion eques?
Actinopterygii Macrouridae? Coryphaenoides?
Actinopterygii Molva dypterygia
Actinopterygii Phycidae
Actinopterygii Chimera?
Actinopterygii Scorpaeniformes?
Actinopterygii Synaphobranchus?
Chimaera monstrosa
Helicolenus dactylopterus
Lepidorhombus boscii
Lophius piscatorius
Macrouridae Coelorinchus
Macrouridae Trachyrincus?
Octopoda
Phycis blennoides
Pleuronectiformes
Scyliorhinus canicula
Species B Ophiuroidea/polychaeta
Species B Ophiuroidea/polychaeta
Species F Tunicata (globose translucent)
Species F Globular translucent
Species F Porifera/tunicate (translucent)
Species J
Species L
Species Q
Species Q Polynoides OTU146
Species U Microbial film
Species V
Species V polychaeta tubes?
Trachyrincus
U. faunal crust
U. faunal turf

Appendix 7. Biomass clustering and ordination

When considering which dataset to use when examining the composition of infaunal communities both within and across boxes, both abundance and biomass metrics were considered. It was decided that based on the near identical patterns of ordinations (Figures A7.1 and A7.2, compared with Figures 14 and 16 respectively) and greater influence of many numerically dominant taxa with very small body sizes (e.g. Nematodes) that abundance data would provide the best insight into infaunal communities at GSH.

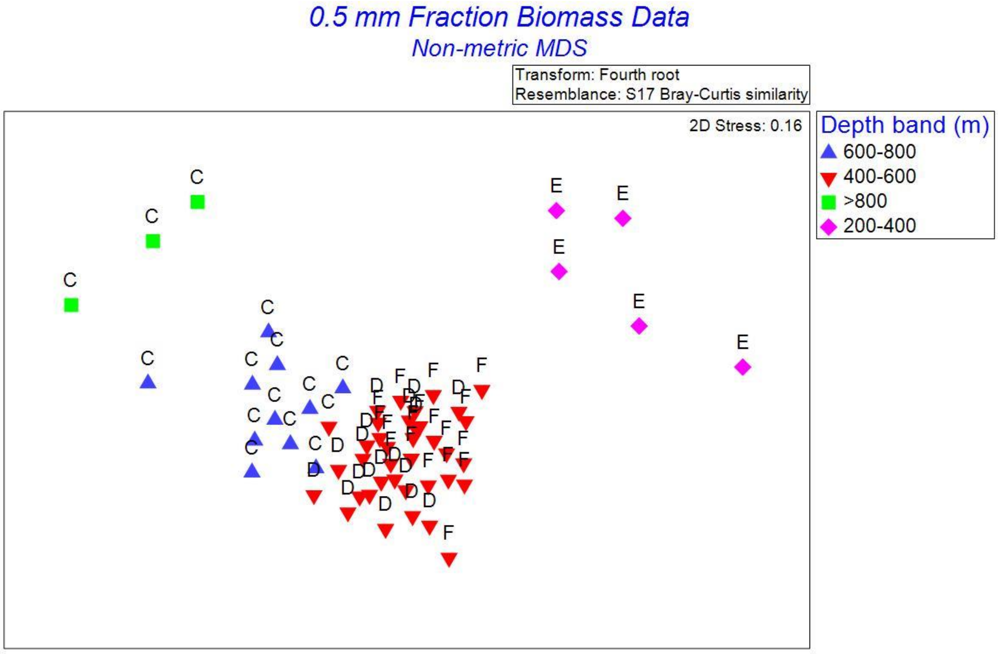


Figure A7.1. nMDS plot of fourth root transformed 0.5 mm infaunal biomass data. To be compared with Figure 14.

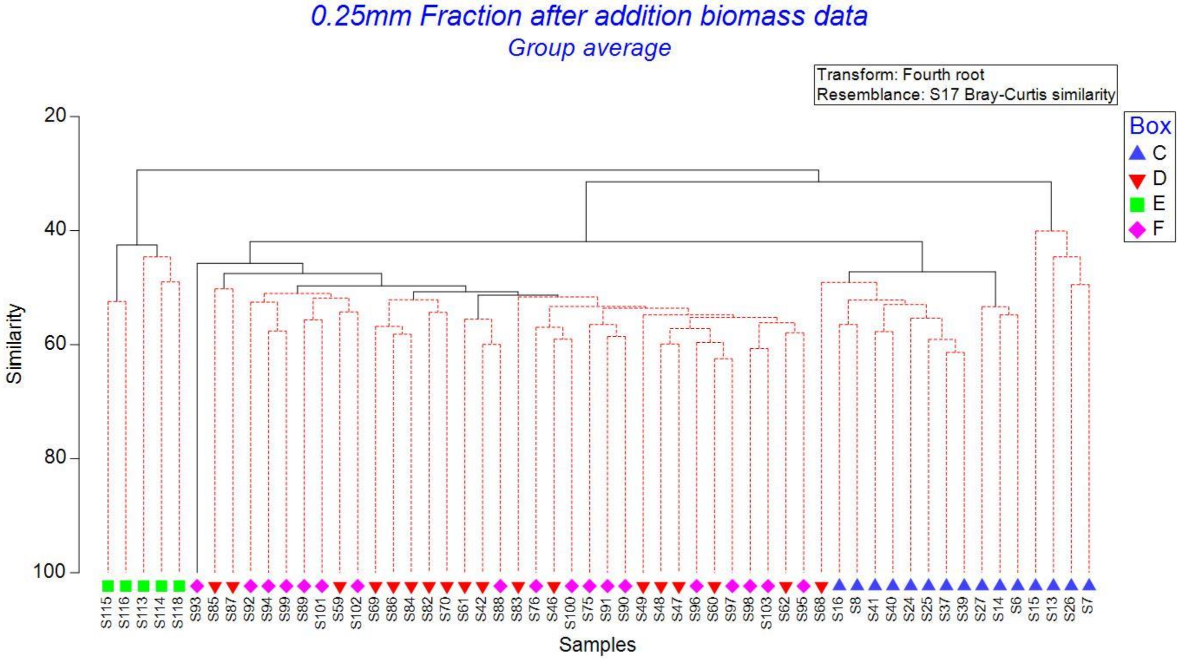


Figure A7.2. Hierarchical agglomerative clustering with group average on 0.5 mm infaunal biomass data by station, labelled with boxes. SIMPROF results are shown by either black solid or red dashed lines. To be compared with Figure 16.

Appendix 8. Reference images of core subsamples

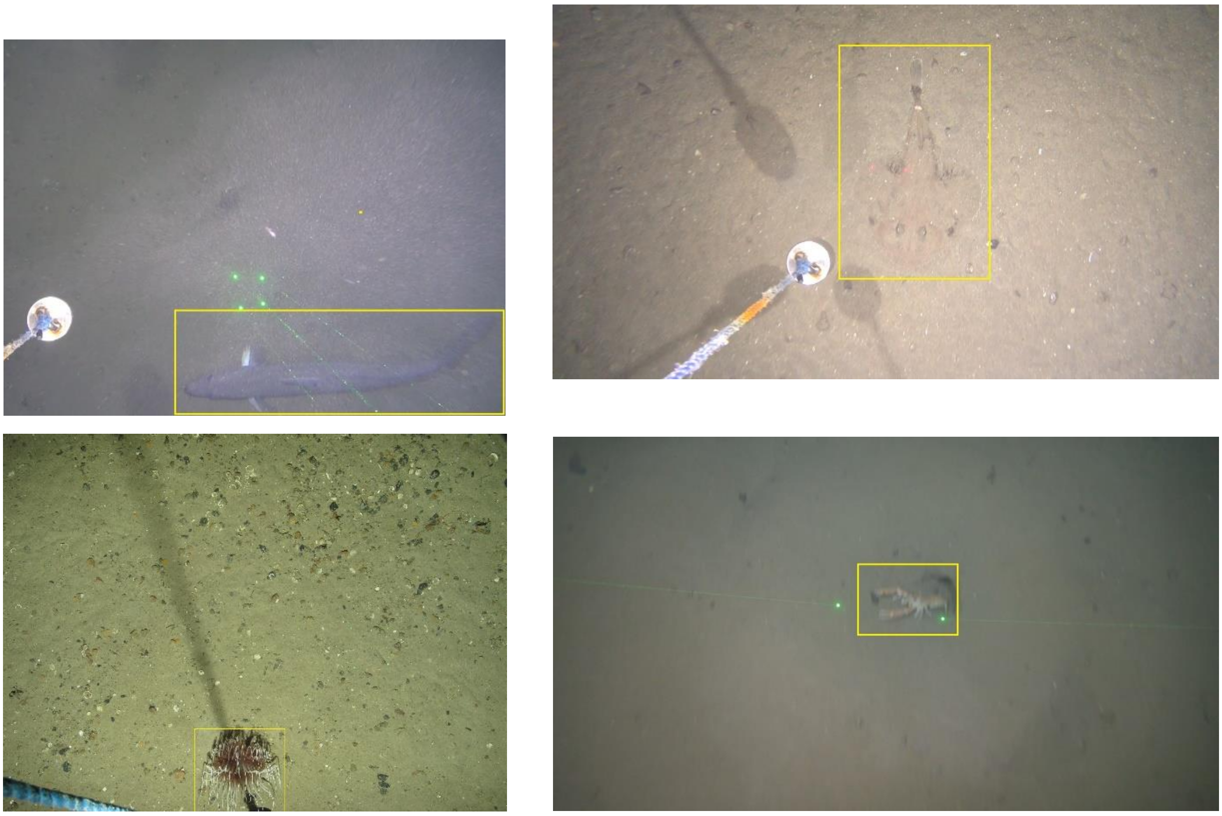
Selection of random samples within each box. Clockwise from top left: C02, D14, F08 and E15. Layering within the cores is clearly evident, as described in the report.

Appendix 9. Reference field photographs of core samples

Selection of random samples within each box. Clockwise from top left: C02, D14, F08 and E15.

Appendix 10. Reference images of taxa of interest

Clockwise from top left: *Molva dypterigya, Lophius piscatorius, Nephrops norvegicus, Pachycerianthus sp.*



Appendix 11. Comparison of 0.5 mm and 0.25 mm sieve fractions

This appendix aims to compare the infaunal assemblages retained on a 0.5 mm and 0.25 mm sieve for monitoring purposes at GSH.

Comparing the patterns described in 3.2.2 across sieve fractions (Figure A12.1), it is apparent that the overall dispersion of samples in multidimensional space are largely equivalent, with samples structured by depth rather than sieve fraction.

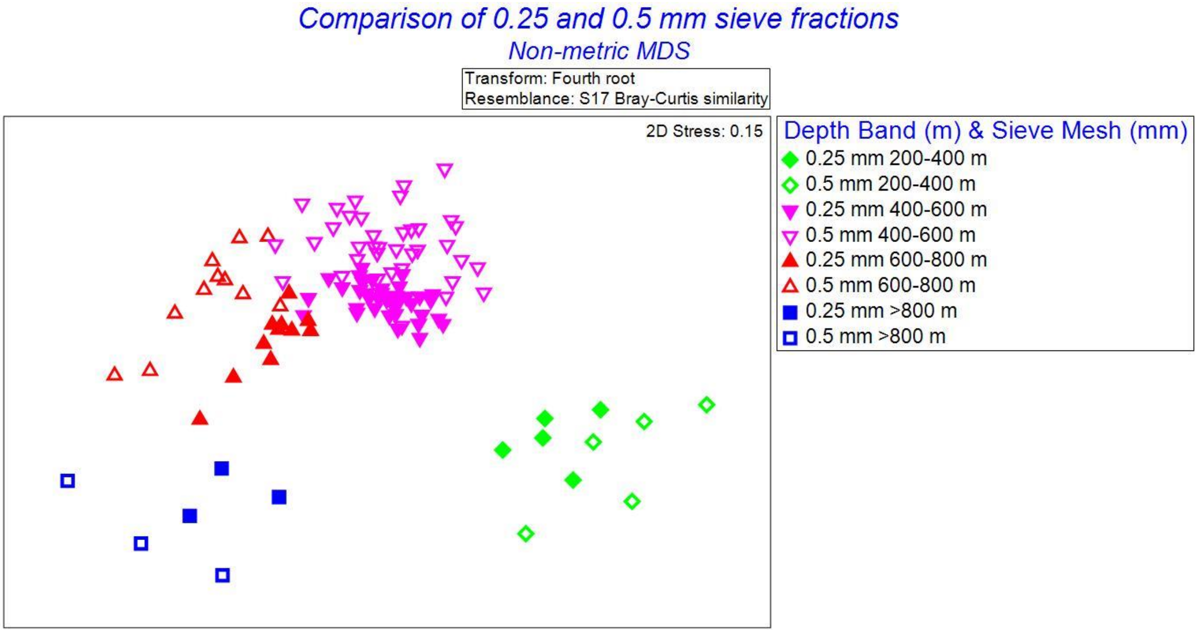


Figure A12.1: nMDS plot of 0.25 mm and 0.5 mm sieve fractions, plotted by depth band (colour) and fraction (filled/empty shape).

Strong separation between Box E and all other samples, poor separation between Boxes D and F and broad intra-box variability in Box C are observable whether a 0.5 mm or 0.25 mm mesh is used. Additionally, two-way (box and sieve mesh) SIMPER analysis shows that dissimilarity between sieve meshes across the site (46.42) is broadly similar to the intra sample variability for either the 0.5 mm (50.96) or 0.25 mm mesh size (59.22) across the site. Ultimately, the 0.25 mm samples show the same observable patterns, albeit with reduced multivariate dispersion. This may, however, be a function of an increased number of individuals in the 0.25 mm fraction (i.e. a greater sample size) which would need to be randomly reduced to enable a fair comparison.

Whilst the same global patterns are evident in both 0.5 mm and 0.25 mm fractions, several taxa, such as nematodes, *Ophiocten abyssicolum,* Nactidae spp*., Ampelisca spp,* and *Eurydice truncata,* are all very rare or absent in the 0.5 mm fraction and are relatively abundant in the 0.25 mm fraction. This is largely driven by smaller mean body size (the transition from macrofauna into meiofauna), which is largely uninformative for MPA monitoring purposes unless there is specific pre-existing rationale for targeting a specific size class of fauna, such as matching to existing datasets collected using a finer sieve mesh.

A more pertinent question is whether or not the global patterns discussed in section 4.2, remain observable irrespective of sieve size. As shown in Figure A12.1, globally observed patterns do exist. Samples from 200-400 m (Box E) are well separated from the other samples and samples from 400-600 m (Boxes D and F) show poor separation from each other. The deepest samples collected (>800 m, Box C) show separation from other depth bands, albeit with greater intra-box variability, especially between some samples from 400-600 m in Boxes D and C where some samples overlap. Again, this interpretation must be considered with the slightly elevated 2D stress value (0.15) relative to Figure 18 in mind.

Outside GSH, there is a wide body of literature on the use of different mesh sizes using a range of gears and in a range of environments from estuarine waters to the deep sea (Gage *et al.* 2002; Danovaro 2009; Philips *et al.* 2014). While the recommendations from these studies are varied, the broad consensus is to use a 1.0 mm mesh for surveys in the continental shelf and a 0.25 mm or 0.3 mm sieve for deep-sea surveys, unless there is pre-existing rationale for using a larger sieve (such as evidence that the fauna to be sampled are larger or to compare with previous studies using a larger sieve).

Notwithstanding, at GSH the presence of a ‘long’ ecological gradient, depth (~200 to over 1500 m), and diverse infaunal communities with the occurrence of deep-sea specific taxa means that the use of a 0.5 mm sieve provides a cost, time and labour effective option to approach monitoring of benthic infauna as global patterns are still observable at this coarser resolution.

While this example provides insight into different sieve fractions at GSH, it should be applied with caution to other MPAs. The presence of a ‘long’ ecological gradient at the site and the prevalence of mud habitats make this interpretation unsuitable for application in other substrata, for example coarse sediments in areas of homogeneous depth, where the relative size classes and diversity of fauna may differ, and thus merit individual investigation.

Appendix 12. Abbreviations and Glossary

Abbreviations

BACI	Before After Control Impact
BSH	Broadscale Habitats
EUNIS	European Nature Information System
GES	Good Environmental Status
JNCC	Joint Nature Conservation Committee
NMBAQC	North East Atlantic Marine Biological Analytical Quality Control Scheme
MESH	Mapping European Seabed Habitats
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NIS	Non-Indigenous Species
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PMF	Priority Marine Feature
PSA	Particle Size Analysis
PSD	Particle Size Distribution
MRV	Motor Research Vessel
SNCB	Statutory Nature Conservation Body

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 affect the marine environment; e.g. fishing, energy production. *****
Anthropogenic	Caused by humans or human activities; usually used in reference to environmental degradation.*
Assemblage	A collection of plants and/or animals characteristically associated with a particular environment that can be used as an indicator of that environment. The term has a neutral connotation and does not imply any specific relationship between the component organisms, whereas terms such as ‘community’ imply interactions (Allaby 2015).
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on or near the seabed are benthos (e.g. sponges, crabs, seagrass beds).*
Biotope	The physical habitat with its associated, distinctive biological communities. A biotope is the smallest unit of a habitat that can be delineated conveniently and is characterised by the community of plants and animals living there. *
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.

Impact	The consequence of pressures (e.g. habitat degradation) where a change occurs that is different to that expected under natural conditions.*
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 Strategy Framework Directive (MSFD)	Environmental Status (GES) of EU marine waters and to protect the resource base upon which marine-related economic and social activities depend.
Marine Protected Area (MPA)	A generic term to cover all marine areas that are ‘A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values’ (Dudley 2008).*
Non-indigenous Species	A species that has been introduced directly or indirectly by human agency (deliberately or otherwise) to an area where it has not occurred in historical times and which is separate from and lies outside the area where natural range extension could be expected (Eno *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).*
Priority Marine Features (PMFs)	Priority marine features are habitats and species that are considered to be marine nature conservation priorities in Scottish 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.
Type 1 (Sentinel) Monitoring of long-term trends	Objective: to measure rate and direction of long-term change. This type of monitoring provides the context to distinguish directional trends from short-scale variability in space and time. To achieve this objective efficiently, a long-term commitment to regular and consistent data collection is necessary; this means time-series must be established as their power in identifying trends is far superior to any combination of independent studies (Kröger & Johnston 2016).
Type 2 (Operational) Monitoring	Objective: to measure state and relate observed change to possible causes. This objective complements monitoring long-term trends and is best suited to explore the likely impacts of anthropogenic pressures on habitats and species and identify emerging problems. It leads to setting of hypotheses about processes underlying observed patterns, and is generally best applied in areas where a gradient of pressure is present (e.g. no pressure

	increasing gradually to ‘high’ pressure) (Kröger & Johnston 2016): It relies on finding relationships between observed changes in biodiversity and observed variability in pressures and environmental factors. It provides inference, but it is not proof of cause and effect. The spatial and temporal scale for this type of monitoring will require careful consideration of the reality on the ground to ensure inference will be reliable; for example, inference will be poor in situations where the presence of a pressure is consistently correlated to the presence of an environmental driver (e.g. a specific depth stratum) (Kröger & Johnston 2016).
Type 3 (Investigative) Monitoring	Objective: to investigate the cause of change. This monitoring type provides evidence of causality. It complements the above types by testing specific hypotheses through targeted manipulative studies (i.e. excluding an impact or causing an impact for experimental purposes). The design and statistical approach that can be used in these cases gives confidence in identifying cause and effect. It is best suited to test state/pressure relationships and the efficacy of management measures (Kröger & Johnston 2016).
Marine and Coastal Access Act (2009)	The Marine and Coastal Access Act provide the legal mechanism to help ensure clean, healthy, safe, productive and biologically diverse oceans and seas by putting in place a new system for improved management and protection of the marine and coastal environment. The Act provides executive devolution to Scottish Ministers of marine planning and nature conservation powers in the offshore region (12 - 200 nautical miles from the mean low water mark).

Appendix 13. Survey box vertices and sample points

Table A16.1: Summary of sample box vertices and sample points as planned. Co-ordinates are presented in decimal degrees using projection EPSG:4326 (WGS84).

Box vertices	Longitude (Decimal degrees)	Latitude (Decimal degrees)	Sample points	Longitude (Decimal degrees)	Latitude (Decimal degrees)
A	-9.58865	58.40479	GSH_A01	-9.65679	58.4262
A	-9.68236	58.42761	GSH_A01	-9.65679	58.4262
A	-9.52155	58.63267	GSH_A02	-9.63152	58.4497
A	-9.4416	58.62021	GSH_A02	-9.63152	58.4497
A	-9.68236	58.42761	GSH_A03	-9.63236	58.4963
A	-9.61671	58.5374	GSH_A03	-9.63236	58.4963
B	-9.55343	58.32924	GSH_A04	-9.60542	58.4265
B	-9.28843	58.52358	GSH_A04	-9.60542	58.4265
B	-9.39669	58.4254	GSH_A05	-9.60623	58.4731
B	-9.47964	58.45157	GSH_A05	-9.60623	58.4731
B	-9.3377	58.51949	GSH_A06	-9.60703	58.5198
B	-9.55343	58.32924	GSH_A06	-9.60703	58.5198
B	-9.58345	58.35755	GSH_A07	-9.58012	58.4499
C	-9.51647	58.3512	GSH_A07	-9.58012	58.4499
C	-9.44004	58.31388	GSH_A08	-9.58089	58.4966
C	-9.51647	58.3512	GSH_A08	-9.58089	58.4966
C	-9.212	58.531	GSH_A09	-9.58167	58.5432
C	-9.13655	58.49026	GSH_A09	-9.58167	58.5432
D	-9.19004	58.36388	GSH_A10	-9.55479	58.4734
D	-9.30671	58.27221	GSH_A10	-9.55479	58.4734
D	-8.97374	58.46964	GSH_A11	-9.55553	58.52
D	-8.92338	58.43888	GSH_A11	-9.55553	58.52
D	-9.36504	58.28888	GSH_A12	-9.55627	58.5667
D	-9.247	58.387	GSH_A12	-9.55627	58.5667
D	-9.36504	58.28888	GSH_A13	-9.53013	58.5435
E	-8.66201	58.32654	GSH_A13	-9.53013	58.5435
E	-8.99996	58.16392	GSH_A14	-9.53084	58.5901
E	-9.06591	58.20418	GSH_A14	-9.53084	58.5901
E	-8.73152	58.36282	GSH_A15	-9.5047	58.5669
E	-8.99996	58.16392	GSH_A15	-9.5047	58.5669
F	-8.89124	58.50461	GSH_A16	-9.50537	58.6136
F	-8.89124	58.50461	GSH_A16	-9.50537	58.6136
F	-8.60671	58.54721	GSH_A17	-9.47923	58.5903
F	-8.80671	58.44721	GSH_A17	-9.47923	58.5903
F	-8.42263	58.6324	GSH_A18	-9.45373	58.6138
F	-8.34838	58.56388	GSH_A18	-9.45373	58.6138
			GSH_B01	-9.57859	58.3566
			GSH_B02	-9.5526	58.3334

Box vertices	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**	**Sample points**	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**
			GSH_B03	-9.55333	58.38
			GSH_B04	-9.52733	58.3568
			GSH_B05	-9.52803	58.4035
			GSH_B06	-9.50203	58.3802
			GSH_B07	-9.5027	58.4269
			GSH_B08	-9.4767	58.4037
			GSH_B09	-9.47733	58.4503
			GSH_B10	-9.45133	58.4271
			GSH_B11	-9.42593	58.4505
			GSH_B12	-9.39997	58.4273
			GSH_B13	-9.4005	58.4739
			GSH_B14	-9.37453	58.4507
			GSH_B15	-9.37503	58.4973
			GSH_B16	-9.34906	58.4741
			GSH_B17	-9.32356	58.4975
			GSH_B18	-9.29802	58.5209
			GSH_C01	-9.47607	58.357
			GSH_C02	-9.45014	58.3338
			GSH_C03	-9.45074	58.3804
			GSH_C04	-9.42481	58.3572
			GSH_C05	-9.39944	58.3806
			GSH_C06	-9.37354	58.3573
			GSH_C07	-9.37403	58.404
			GSH_C08	-9.34814	58.3807
			GSH_C09	-9.3486	58.4274
			GSH_C10	-9.3227	58.4042
			GSH_C11	-9.32313	58.4508
			GSH_C12	-9.29723	58.4275
			GSH_C13	-9.29763	58.4742
			GSH_C14	-9.27173	58.4509
			GSH_C15	-9.24619	58.4743
			GSH_C16	-9.22062	58.4977
			GSH_C17	-9.19476	58.4744
			GSH_C18	-9.16915	58.4978
			GSH_D01	-9.34722	58.2874
			GSH_D02	-9.32185	58.3108
			GSH_D03	-9.29606	58.2875
			GSH_D04	-9.29645	58.3342
			GSH_D05	-9.27066	58.3109
			GSH_D06	-9.27101	58.3576
			GSH_D07	-9.24522	58.3343
			GSH_D08	-9.24554	58.381

Box vertices	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**	**Sample points**	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**
			GSH_D09	-9.21975	58.3577
			GSH_D10	-9.19424	58.3811
			GSH_D11	-9.1687	58.4044
			GSH_D12	-9.14294	58.3811
			GSH_D13	-9.11737	58.4045
			GSH_D14	-9.06604	58.4045
			GSH_D15	-9.0404	58.4279
			GSH_D16	-9.01472	58.4512
			GSH_D17	-8.98903	58.4279
			GSH_D18	-8.96332	58.4512
			GSH_E01	-9.04013	58.1945
			GSH_E02	-9.01463	58.2179
			GSH_E03	-8.9891	58.1945
			GSH_E04	-8.96356	58.2179
			GSH_E05	-8.93807	58.1945
			GSH_E06	-8.93799	58.2412
			GSH_E07	-8.9125	58.2178
			GSH_E08	-8.91238	58.2645
			GSH_E09	-8.88689	58.2412
			GSH_E10	-8.86125	58.2645
			GSH_E11	-8.83558	58.2878
			GSH_E12	-8.81012	58.2644
			GSH_E13	-8.80987	58.3111
			GSH_E14	-8.78441	58.2877
			GSH_E15	-8.75867	58.311
			GSH_E16	-8.7329	58.3343
			GSH_E17	-8.70748	58.3109
			GSH_E18	-8.68167	58.3342
			GSH_F01	-8.86033	58.4978
			GSH_F02	-8.83471	58.4745
			GSH_F03	-8.80886	58.4978
			GSH_F04	-8.78327	58.4744
			GSH_F05	-8.78298	58.521
			GSH_F06	-8.75739	58.4977
			GSH_F07	-8.73148	58.521
			GSH_F08	-8.70553	58.5442
			GSH_F09	-8.654	58.5441
			GSH_F10	-8.62798	58.5674
			GSH_F11	-8.57641	58.5672
			GSH_F12	-8.55033	58.5904
			GSH_F13	-8.52484	58.567
			GSH_F14	-8.49872	58.5903

Box vertices	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**	**Sample points**	**Longitude (Decimal degrees)**	**Latitude (Decimal degrees)**
			GSH_F15	-8.47327	58.5668
			GSH_F16	-8.44712	58.59
			GSH_F17	-8.4217	58.5666
			GSH_F18	-8.42093	58.6133

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