Lundy Special Area of Conservation (SAC) Monitoring Report 2017

Marine Protected Area (MPA) Monitoring Programme

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Abbreviations

ANOSIM	Analysis of Similarity
BACI	Before-After-Control-Impact
BPI	Bathymetric Position Index
BSH	Broadscale Habitats
CAL	Chemical Action Level
CCME	Canadian Council of Ministers of the Environment
CD	Chart Datum
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CoV	Coefficient of Variation
CP2	Charting Progress 2
DDV	Drop-Down Video
Defra	Department for Environment, Food and Rural Affairs
DSIFCA	Devon and Severn Inshore Fisheries and Conservation Authority
EA	Environment Agency
EAC	Environmental Assessment Criteria
EC	European Commission
ERL	Effects Range Low
ERM	Effects Range Median
EUNIS	European Nature Information System
FOCI	Feature of Conservation Interest
FoV	Field of View
FP	Floating Point
GLCM	Gray-Level Co-occurrence Matrix
GMA	General Management Approach
HCBD	Hexachlorobutadiene
HD	High Definition
ISQG	International Sediment Quality Guidelines
JNCC	Joint Nature Conservation Committee
LOD	Limit of Detection
NIS	Non-indigenous Species

NMBAQC	Northeast Atlantic Marine Biological Analytical Quality Control Scheme
NOAA	National Oceanic and Atmospheric Administration
MESH	Mapping European Seabed Habitats project
MBES	Multibeam echosounder
MCZ	Marine Conservation Zone
MNR	Marine Nature Reserve
MPA	Marine Protected Area
MSFD	Marine Strategy Framework Directive
NE	Natural England
NIS	Non-Indigenous Species
OBIA	Object-based Image Analysis
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PAH	Polycyclic Aromatic Hydrocarbon
PBDE	Polybrominated Diphenyl Ether
PCB	Polychlorinated Biphenyls
PEL	Probable Effect Level
PREMIAM	Pollution Response in Emergencies: Marine Impact Assessment and Monitoring
PSA	Particle Size Analysis
PSD	Particle Size Distribution
ROG	Recommended Operating Guidelines
RV	Research Vessel
SAC	Special Area of Conservation
SACO	Supplementary Advice on Conservation Objectives
SAGA	System for Automated Geoscientific Analyses
SIMPER	Similarity Percentages analysis
SIMPROF	Similarity Profile analysis
SQG	Sediment Quality Guidelines
SNCB	Statutory Nature Conservation Body
SOCI	Species of Conservation Interest
SSI	Simple Structure Index

SSS	Side scan sonar
STR	Subsea Technologies and Rentals
TBT	Tributyl tin
TEL	Threshold Effect Level
TRV	Toxicity Reference Value
USEPA	United States Environmental Protection Agency

Executive Summary

This monitoring report is informed by data acquired during a dedicated survey carried out at the Lundy Special Area of Conservation (SAC) during 2017, which will form part of the ongoing time series data and evidence programme for this Marine Protected Area (MPA).

Lundy SAC is an inshore MPA located off the northern coast of Devon and Cornwall within the 'Western Channel and Celtic Sea' Charting Progress 2 (CP2) sea area. The SAC was primarily designated for the Annex I habitat 'Reefs', with other qualifying features including 'Sandbanks which are slightly covered by sea water all the time'.

The 2017 survey acquired infaunal, sediment particle size and sediment contaminants data from grab samples, and epibiotic data using a drop-down video approach; allowing a characterisation of the chemical, physical, and biological characteristics of the habitats present within the SAC. The grab samples revealed that four sediment EUNIS Level 3 habitat classes ('A5.1 Sublittoral coarse sediment' and 'A5.2 Sublittoral sand', both of which equate to Annex I Sandbank feature habitats, and 'A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments') were observed across the 98 grab samples. The Annex I Sandbank feature habitat 'A5.1 Sublittoral coarse sediment' was significantly more species rich than the other three habitats and possessed high infaunal abundances. In contrast, 'A5.2 Sublittoral sand', which is also an Annex I Sandbank feature habitat, was the least speciose sedimentary habitat within the SAC. In general, Annex I Sandbanks feature habitats were distinguished from non-Sandbank habitats by greater numbers of the Ross worm *Sabellaria spinulosa* and the pea urchin *Echinocyamus pusillus*, and fewer numbers of annelid worms more commonly associated with finer sediments such as *Mediomastus fragilis* and *Scalibregma inflatum*.

Infaunal multivariate structure was related to EUNIS habitat class, with the largest differences being observed between 'A5.1 Sublittoral coarse sediment' and 'A5.4 Sublittoral mixed sediments'. Eight biotopes were assigned across the 98 grab samples: 95 % at the EUNIS Level 5. The two most prevalent biotope classifications were A5.132 (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) and A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment).

Epibiotic data acquired from the imagery approaches revealed three habitat classes present within the Lundy SAC; 'A3.1 Atlantic and Mediterranean high energy infralittoral rock', 'A4.1 Atlantic and Mediterranean high energy circalittoral rock' and 'A4.2 Atlantic and Mediterranean moderate energy circalittoral rock'. These hard substrate habitats presented a clear geographical separation, primarily associated with depth, tidal flow, and east-west shore of Lundy. Although a full investigation of Annex I Reef or Stony Reef subtypes was not possible, examples of Annex I Reef

features ‘bedrock reef’, ‘stony reef’ and ‘bedrock and/or stony (potential)’ habitats were observed based on the camera still images.

The 2017 sediment data were used to groundtruth previously acquired acoustic data (2015) from a region to the east of Lundy, to produce a geomorphological and sediment map. The data revealed a low (~10 m high), broad (more than 1.2 km) sandbank which occupies most of the area surveyed, apart from the southern section where bedrock is observed.

The three fisheries management zones within the Lundy SAC were compared based on their sediment particle size distributions and infaunal assemblages. This comparison was based on two contrasting sampling designs: 38 single replicate samples and 12 intensively sampled boxes (five replicates within each). Both sediment particle size and associated infaunal communities displayed large spatial variability within each of the three zones. This inherently reduced the capacity to detect any statistical differences which may have been present between zones.

Recommendations are presented for improving data quality and refining target metrics for future monitoring of the Lundy SAC based on the findings in the report. Key recommendations include ensuring sampling location consistency between surveys, the acquisition of acoustic data for the whole SAC (to augment the relatively small area collected hitherto), and greater efforts to acquire better quality video and stills photography data to aid the assessment of reef quality. Additionally, the observed small-scale (within some intensively sampled boxes) variability in sediment particle size analysis (PSA) and infaunal assemblages, implies that stations vary with respect to their suitability for monitoring changes associated with any fisheries management approaches.

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1 Introduction

The Lundy Special Area of Conservation (SAC) was originally designated to meet conservation objectives under the European Commission (EC) Habitats Directive, and is part of an ecologically coherent network of Marine Protected Areas (MPAs) within UK waters. It also contributes to the OSPAR network of MPAs across the North-East Atlantic. The site is also a Marine Conservation Zone (MCZ) but is not designated for any habitat features.

This monitoring report primarily explores data acquired from the first dedicated monitoring survey of Lundy SAC, conducted during 2017. The specific aims of the report are discussed in more detail in Section 1.4.

1.1 Site overview

Lundy SAC is an inshore site on the northern coast of Devon (Figure 1) and is located in the jurisdictional area of the Devon and Severn Inshore Fisheries Conservation Authority (DSIFCA). It falls within the wider 'Charting Progress 2' (CP2) area 'Western Channel and Celtic Sea'. The site was established as England's first Marine Nature Reserve (MNR) in 1986 and was converted to a MCZ in 2013. The MCZ boundary corresponds to the existing SAC boundary and provides additional protection for the spiny lobster (*Palinurus elephas*). Lundy SAC falls within the designated area for the Bristol Channel Approaches/Dynesfeydd Môr Hafren SAC (designated in February 2019; harbour porpoise; *Phocoena phocoena*). Lundy SAC is also neighboured by a number of designated MPAs (see Figure 1).

The Lundy SAC encompasses a rectangular area of 31 km^2 around Lundy, an island off the North Devon coast in the Bristol Channel (Arnold and Miller, 2019). It is subjected to strong tidal currents and wave activity resulting in complex biological communities. The site is considered a 'biodiversity hotspot' due to its reef, sublittoral sand and coarse sediment habitats (Natural England, 2017). The site was primarily designated due to the presence of high-quality Annex I 'Reef' features, although additional qualifying features include 'Sandbanks which are slightly covered by sea water all the time', 'Submerged or partially submerged sea caves' and the grey seal (*Halichoerus grypus*)[1] (Table 1). The area around Lundy is characterised by a granite and slate reef system, and the island possesses both exposed and sheltered areas of coastline which are subject to varying tidal flow and wave action. The reef areas extend offshore from the island, descending steeply to approximately 40 m depth in places. Reef-associated biota include soft corals (e.g., *Parerythropodium coralloides* and *Eunicella verrucosa*), cup corals (e.g., *Balanophyllia regia* and *Leptopsammia pruvoti*), erect branching sponges, and many species of seaweed.

[1] Designated Sites - Lundy Marine Protected Area

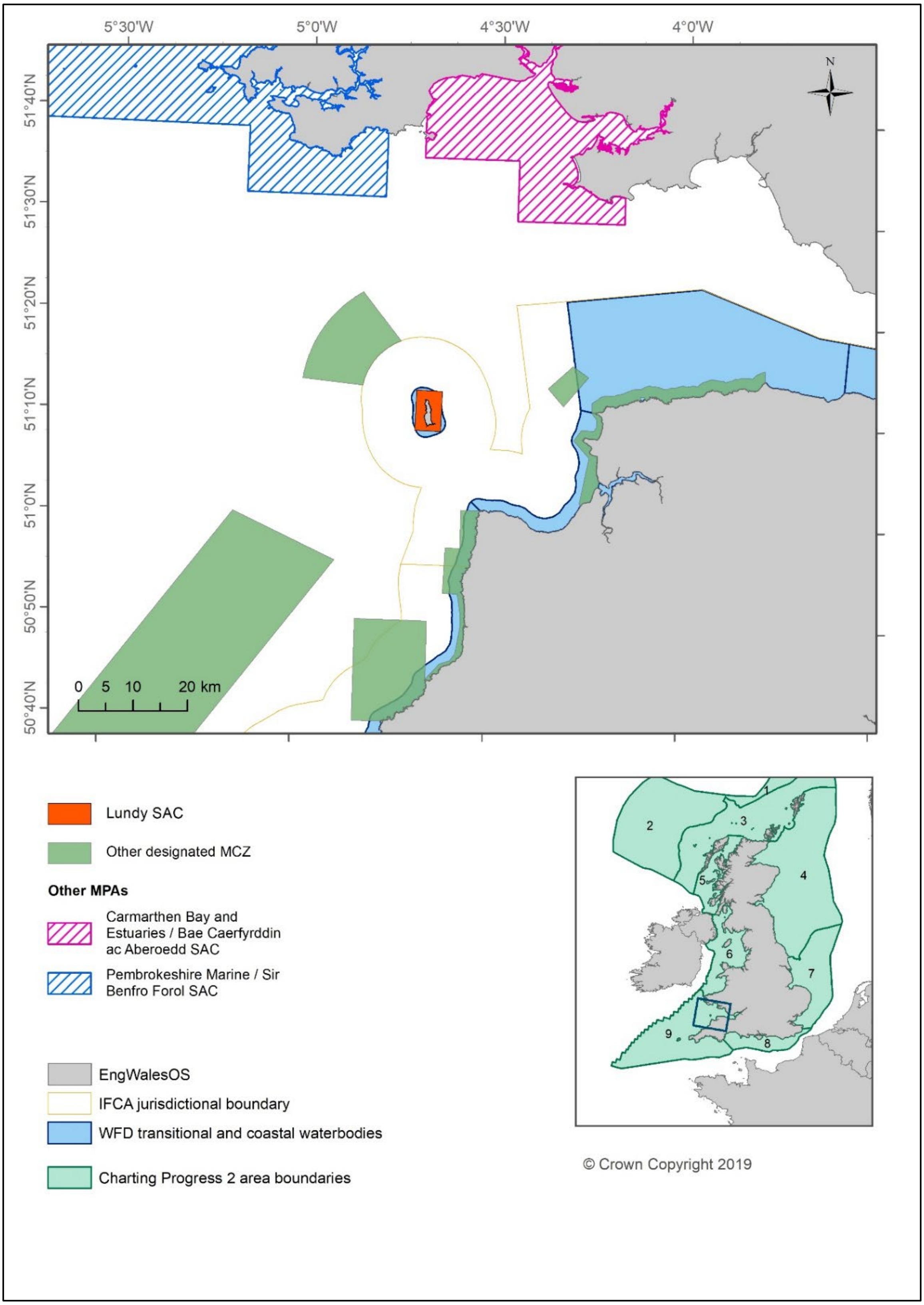

Figure 1. Location of the Lundy SAC in the context of MPAs and management jurisdictions proximal to the site.

Table 1. Designated Annex I features and subfeatures within the Lundy SAC (Natural England, 2017) (© Natural England and Cefas 2022). This monitoring report focuses on the features in bold.

SAC Feature Type	Annex I Features	Annex I Subfeatures (with corresponding EUNIS code)
Habitat	**H1170 Reefs**	**A4 Circalittoral rock**
	H1170 Reefs	**A3 Infralittoral rock**
	H1170 Reefs	A1 Intertidal rock
	H1110 Sandbanks which are slightly covered by sea water all the time	**A5.1 Sublittoral coarse sediment**
	H1110 Sandbanks which are slightly covered by sea water all the time	**A5.2 Sublittoral sand**
	H8330 Submerged or partially submerged sea caves	N/A
Species	S1364 Grey seal (*Halichoerus grypus*)	A2.1 Intertidal coarse sediment
		A1 Intertidal rock
		Submerged or partially submerged sea caves
		SH_3 Water column

1.2 Management of activities at Lundy SAC

Fisheries activity across the Lundy SAC is managed by the Devon and Severn Inshore Fisheries Conservation Agency (DSIFCA) via fishing permit byelaws. To undertake this, the SAC is categorised into several zones, each with specific fishing restrictions (Table 2) (Parkhouse, 2016). Zone 1 (Annex 1a of the DSIFCA's Mobile Fishing Permit Byelaw) which occupies the north-eastern part of the site, allows access to towed demersal trawl gear but not dredges. This came into force on the 1st January 2014. A limited area of Zone 1 (Annex 1b) is open to scallop dredges while the rest of the zone was shut to scallop dredges on 28th July 2017. However, there is no history of scallop dredging occurring at the site and there is currently no scallop dredge fishery. A small amount of potting takes place, towards the southern part of Zone 1, where it does not overlap with the trawling. The area of Zone 1 open to trawling represents a small part of Zone 4, or the ‘squid fishery area’, which lies mainly outside the SAC. As this is a very small and sporadic fishery within the area, and no such activity has taken place during 2014 to 2018 (L. Parkhouse, DSIFCA; pers. comm.), seabed data acquired from within Zone 4 during 2017 were considered to represent those of Zone 1.

Zone 2, which occupies the largest part of the SAC, especially to the south and the west coast of Lundy (Figure 2) is open to potting and angling, has limited access for netting, and is closed to all demersal towed gear. Zone 3, the ‘no take zone’ occupying the inshore area of the east coast of Lundy, was established in 2003. No sea fish resources can be removed by any means within this area. Finally, the removal of spiny lobsters is prohibited by any means with the SAC, and no spearfishing can be carried out in the SAC.

Table 2. Summary of fishing management zones within the Lundy SAC (taken from Arnold and Miller, 2019, © Environment Agency 2017).

Zone name	Zone No.	Start year	Features	Further information
General Use Zone	1	2014	Demersal gear allowed. No spear fishing allowed.	Five vessels known to DSIFCA fished in this zone using otter and multi-rig trawls to fish for squid between May and August only.
No Access Zone	2	2014	No demersal gear allowed. No spear fishing allowed.	Six vessels over 11 m in length known to DSIFCA undertook potting in this zone for European Lobster (*Homarus gammarus*), Brown Crab (*Cancer pagurus*) and Spider Crab (*Maja squinado*) (Parkhouse, 2016).

Zone name	Zone No.	Start year	Features	Further information
No Take Zone	3	2003	No fishing or collection of sea life of any kind.	DSIFCA Byelaw 28[2].
Squid Fishery Zone	4	Unknown	Small, seasonal squid fishery which overlaps General Use Zone.	Small-scale, seasonal fishery (May to August). The fishery did not take place in 2015 or 2016 and had not occurred up to the time of survey in 2017 (Parkhouse, 2016).

[2] lundy-mcz.pdf (landmarktrust.org.uk)

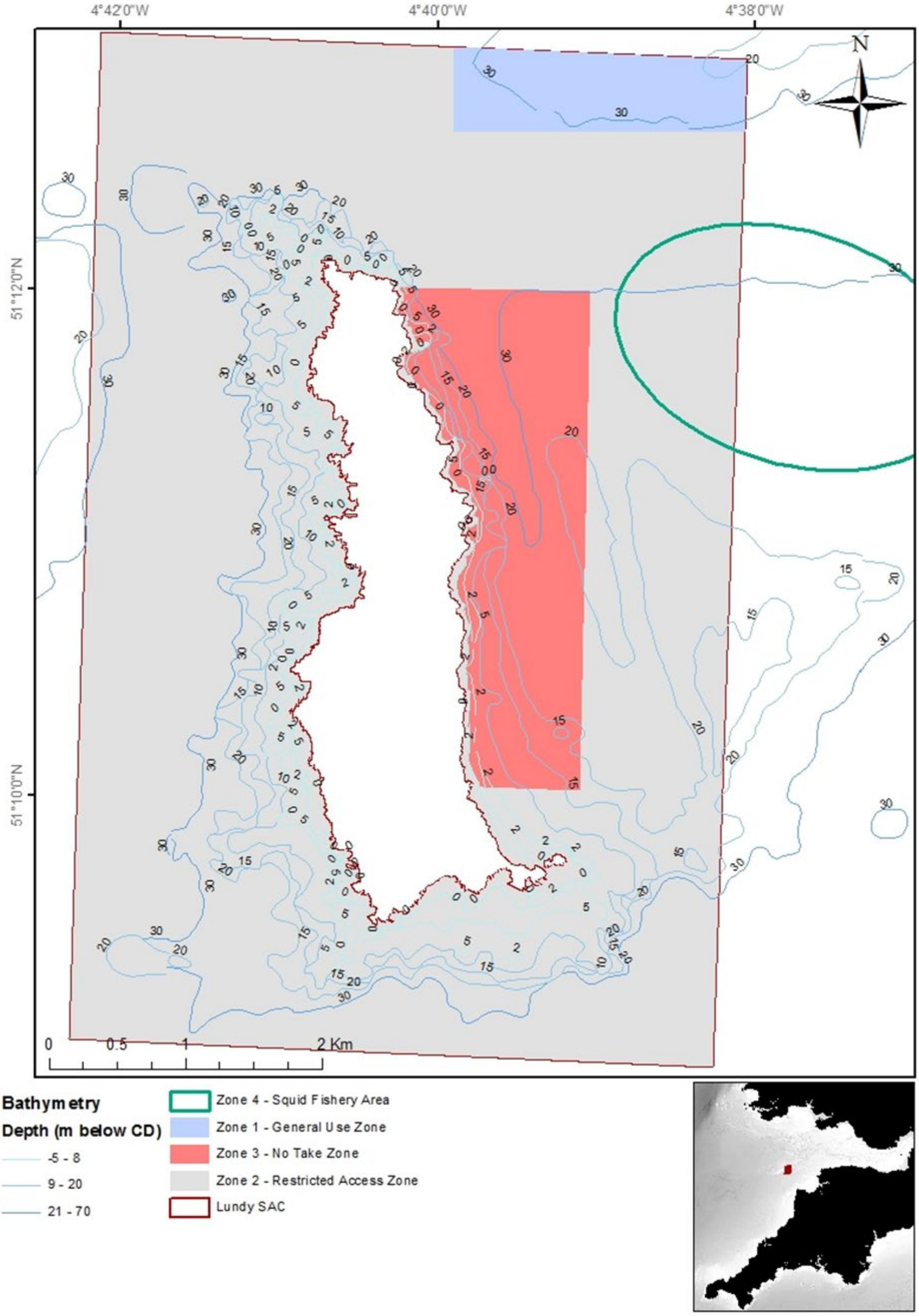

Figure 2. Site and management overview of Lundy SAC, showing locations and extents of management zones alongside bathymetric contours (DEFRA Marine DEM, 2017) (© Natural England and Cefas 2022).

1.3 Existing data and habitat maps

The Lundy SAC has been the subject of several sampling surveys during the past few decades. These surveys have acquired a range of data types (e.g. video imagery, grab samples for sediment PSA, contaminants and infauna, and acoustic data) using a variety of approaches governed by the specific objectives of each survey. In 2007, a grab survey (using a 0.04 m^2 grab) consisting of 52 stations (a small number comprising replicates) was conducted to acquire infaunal and PSA data to allow the production of a biotope map (Natural England, 2008). In 2012, a subsequent survey commissioned by Natural England was conducted using a 0.1 m^2 Day grab. In addition to the acquisition of sediments for PSA and infauna, the 2012 survey sampled a small number of stations (six) for sediment contaminants. Due to differences in the sampling and processing techniques between surveys, and the lack of spatial coincidence of the stations sampled (only *circa* four stations from 2012 were within a 100 m diameter bullring of samples taken in 2017), the data are not considered sufficiently compatible for direct comparisons with those from 2017. However, the sediment contaminants data acquired from the small number of stations sampled along the east coast of Lundy in 2012 and 2017 allow broad temporal comparisons.

A previously developed habitat map for the Lundy SAC has been provided by Natural England as part of the “Marine Habitats and Species Open Data” publicly available layers (Natural England, 2020). This is a composite mapping product, derived principally from three survey campaigns and mapping projects (Envision Mapping Ltd., 1996; Ambios EC Ltd. and Aquatronics, 2008; RPS, 2013) and is presented in Figure 3. This map is referred hereafter as the “Open Data Habitat Map”.

Multibeam echosounder (MBES) bathymetry and backscatter data were opportunistically collected in January 2015 during a survey of the Cape Bank MCZ (CEND0115, Murray *et al*., 2016). The data acquired covered a relatively small proportion of the Lundy SAC, limited to 5.2 km^2 along the east coast of Lundy (Figure 3).

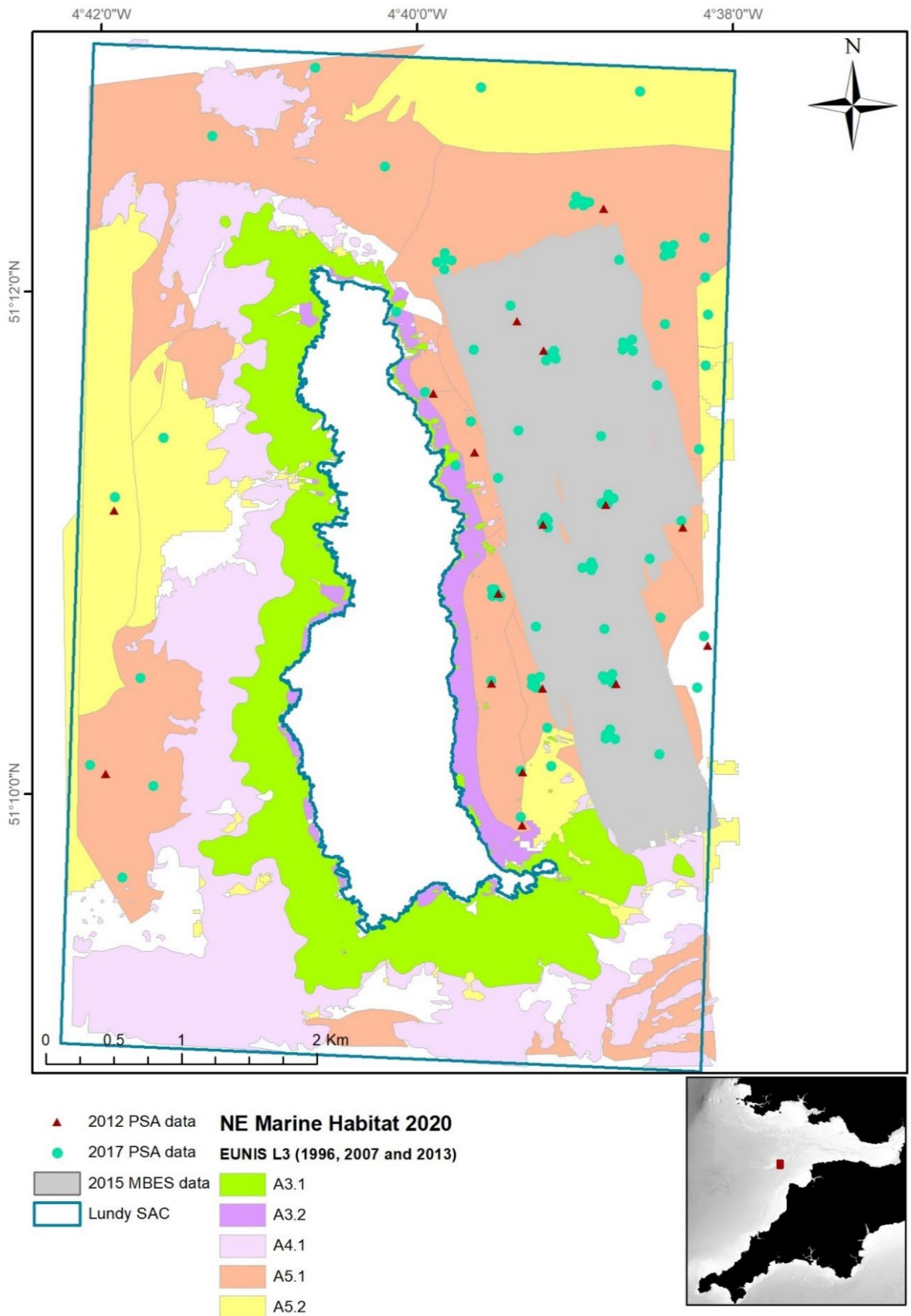

Figure 3. Coverage of the acoustic data collected in 2015 for the Lundy SAC (© Natural England and Cefas 2022). The locations of stations sampled in 2012 and 2017 for which the data represent potential for groundtruthing the acoustic data are also presented, overlying the 2020 Open Data Habitat Map (NE, 2020).

1.4 Aims and objectives

1.4.1 High-level conservation objectives

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

As detailed in conservation advice for the Lundy SAC[3] (Natural England, 2018), the conservation objective for the site is to 'ensure that the integrity of the site is maintained or restored as appropriate, and ensure that the site contributes to achieving the Favourable Conservation Status of its Qualifying Features, by maintaining or restoring:

- the extent and distribution of qualifying natural habitats;
- the structure and function (including typical species) of qualifying natural habitats, and;
- the supporting processes on which the qualifying natural habitats rely.'

The Supplementary Advice for the Conservation Objectives (SACO)[4] for Lundy SAC provides more detailed conservation objectives for feature attributes of the sites designated features (Natural England, 2018).

The extent of a habitat feature refers to the total area in the site occupied by the qualifying feature and must also include consideration of its distribution. A reduction in feature extent has the potential to alter the physical and biological functioning of sediment habitat types (Elliott *et al*., 1998). The distribution of a habitat feature influences the component communities present and can contribute to the condition and resilience of the feature (JNCC, 2004).

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

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[3]https://designatedsites.naturalengland.org.uk/Marine/MarineSiteDetail.aspx?SiteCode=UK0013114&SiteName=lundy&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&HasCA=1&NumMarineSeasonality=1&SiteNameDisplay=Lundy%20SAC

[4]https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UK0013114&SiteName=lundy&SiteNameDisplay=Lundy+SAC&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=1

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

1.4.2 Report aims and objectives

The primary aim of this monitoring report is to explore and describe the attributes of the designated features within Lundy SAC, to enable future assessment and monitoring of feature condition (Table 3). The results presented will be used to develop recommendations for future monitoring, including the testing of specific metrics, which may indicate whether the condition of the feature has been maintained, is improving or is in decline.

The broad objectives of this monitoring report have been modified from those originally established in cognisance of the limitations of the data. Limited comparability of the 2017 data with those acquired during 2007 and 2012 prevented a number of the original reporting objectives to be either partially or fully addressed. These limitations and the rationale behind the revised reporting objectives are described in Appendix 1. The objectives of this report are:

1) Provide a description of the **extent**[5]**, distribution,** and **structural** attributes, and the **supporting processes**, of the designated features within the site, to enable subsequent condition monitoring and assessment (see Table 3 for more detail).

2) Conduct a temporal comparison of contaminant levels between 2012 and 2017.

3) Conduct a spatial comparison of intensely sampled boxes within different fisheries management zones, in terms of infaunal communities and particle size distribution.

4) Evaluate wider spatial variability of infauna and particle size distribution, within and across fisheries management areas.

5) Compare the spatial variability of infauna and particle size distribution between the intensively sampled boxes approach and wider sampling approach.

6) Produce a geomorphological and sediment map for the region of SAC where acoustic data exist.

[5] Note that where current habitat maps are not available, extent will be described within the limits of available data.

7) Compare the abundance and distribution of non-indigenous species between 2012 and 2017.

8) Note observations of any Habitat or Species Features of Conservation Importance (FOCI) not covered by the Designation Order as features of the site.

9) Present evidence relating to marine litter.

10) Provide practical recommendations for appropriate future monitoring approaches (e.g., metric selection, survey design, data collection approaches) with a discussion of their requirements.

1.4.3 Feature attributes and supporting processes

To achieve Objective 1, the report will present evidence on several feature attributes and supporting processes, as defined in the SACO developed by Natural England for the designated features within Lundy SAC[6]. It should be noted that it was not possible to address all feature attributes in the monitoring survey design (e.g., supporting processes: water quality – nutrients; water quality – dissolved oxygen), given the comprehensive nature of the attribute lists for each feature. The feature attributes were therefore rationalised and prioritised, resulting in a smaller sub-set.

The list of selected feature attributes and supporting processes considered in this report, alongside the generated outputs for each, is presented in Table 3.

[6] https://designatedsites.naturalengland.org.uk/Marine/SupAdvice.aspx?SiteCode=UK0013114&SiteName=lundy&SiteNameDisplay=Lundy+SAC&countyCode=&responsiblePerson=&SeaArea=&IFCAArea=&NumMarineSeasonality=1

Table 3. Report objectives and outputs for the Lundy SAC (© Natural England and Cefas 2022).

Objective		Feature Attribute*	Features / Entire SAC	Output
Objectives 1 & 6	Provide a description of the **extent, distribution and structural** attributes of the designated features within the site (see Table 1 for more detail), to enable subsequent condition monitoring and assessment;	Extent and distribution	**Reefs** A3 Infralittoral rock A4 Circalittoral rock **Sandbanks** A5.1 Sublittoral coarse sediment A5.2 Sublittoral sand	Updated sediment and geomorphological map
		Physical structure	**Reefs** A3 Infralittoral rock A4 Circalittoral rock	Stony reef assessment (as per Duncan and Pinder, 2019)
		Sediment composition and distribution	**Sandbanks** A5.1 Sublittoral coarse sediment A5.2 Sublittoral sand	Mapped distribution and description of PSA results Entropy analysis of PSA results
		Presence and spatial distribution of biological communities	**Reefs** A3 Infralittoral rock A4 Circalittoral rock **Sandbanks** A5.1 Sublittoral coarse sediment	Conduct multivariate analysis of infaunal and epifaunal data to: - Identify patterns in biological assemblages - Assign biotopes (for reefs, where possible)

Objective		Feature Attribute*	Features / Entire SAC	Output
		Presence and abundance of key structural and influential species Species composition of component communities	A5.2 Sublittoral sand	- Describe variance in biological assemblage structure within and between habitats - Identify key structural and influential species - Identify any potential indicator taxa
		Supporting processes: energy and exposure	Entire SAC	Generate and describe a tidal model for the site
Objective 2	Temporal assessment of contaminant concentrations	n/a	Entire SAC	Generate maps of concentrations and comparisons with reference threshold values
Objective 3	Spatial comparison of intensely sampled boxes within different fisheries management zones	n/a	Entire SAC	Figures of sediment PSA and infaunal metrics of community structure between zones
Objective 4	Evaluate wider spatial variability within and across fisheries management areas	n/a	Entire SAC	Figures of sediment PSA and infaunal metrics of community structure between zones

Objective		Feature Attribute*	Features / Entire SAC	Output
Objective 5	Comparison of spatial variability between intensively sampled boxes approach with that from wider sampling	n/a	Entire SAC	Comparison of mean coefficient of variation of sediment PSA and infaunal metrics of community structure
Objectives 7 & 9	Present evidence relating to non-indigenous species and marine litter	n/a	Entire SAC	Point map of observations
Objective 8	Note observations of any habitat or species FOCI not covered by Designation Order as features of the site	n/a	Entire SAC	Point map of observations
Objective 10	Provide practical recommendations for appropriate future monitoring approaches for the designated features (e.g. metric selection, survey design, data collection approaches) with a discussion of their requirements	n/a	Entire SAC	Recommendations section

2 Methods

2.1 Survey design

A dedicated monitoring survey was conducted at the Lundy SAC between June 26th and August 13th 2017, aboard the *Severn Guardian* (Arnold and Miller, 2019).

The survey employed both grab sampling and imagery approaches to acquire data for the sedimentary and rock sub features, respectively.

The design adopted for the grab sampling fundamentally comprised two contrasting approaches: single sampling at a suite of stations across the SAC, and replicate sampling at a smaller sub-set of stations (or ‘intensively sampled boxes’) (Figure 3). Individual sample locations were chosen though a combination of stratified random sampling within each of the fisheries management zones, and re-sampling of 16 stations that were previously sampled in 2012. The ‘intensively sampled box’ locations were chosen within the interpreted subtidal coarse sediments through a combination of randomly selected stations and re-sampling of the 2012 sampling box stations. To ensure the survey captured data from which the reporting objectives (Section 1.4.2) could be met, the stations were positioned in accordance with the four fisheries management zones (‘zones’ hereafter; Figure 4) outlined in Section 1.2. However, for the purposes of the present report and the numerical analyses undertaken herein, the data acquired from the squid fishery zone (Zone 4) are analysed as representing Zone 1 (in which the squid fishery zone is located). This decision is based on the rationale that, for the period since the intervention of Zone 4 in 2014 and that of the 2017 survey, no squid fishing has been undertaken (Section 1.2; Arnold and Miller, 2019).

Twelve intensively sampled 100 m x 100 m boxes (five replicates at each) were sampled; four in each of the three zones (Zones 1, 2 and 3; Figure 4) using a mini Hamon grab (0.1 m^2). Single replicate samples using this grab type were also acquired at 38 stations across the area (Figure 4). The samples obtained from both sampling approaches were used to determine infaunal assemblage composition and sediment particle size distribution. In addition, a 0.1 m^2 Day grab was used to sample sediments at five stations along the east coast of Lundy for PSA, nutrients and contaminant concentrations.

To acquire data for the non-sedimentary reef areas, 30 stations were surveyed using a drop-down video (DDV) approach. Apart from one station located just inside Zone 3, all DDV stations were positioned inside the restricted access zone (Zone 2; Figure 5).

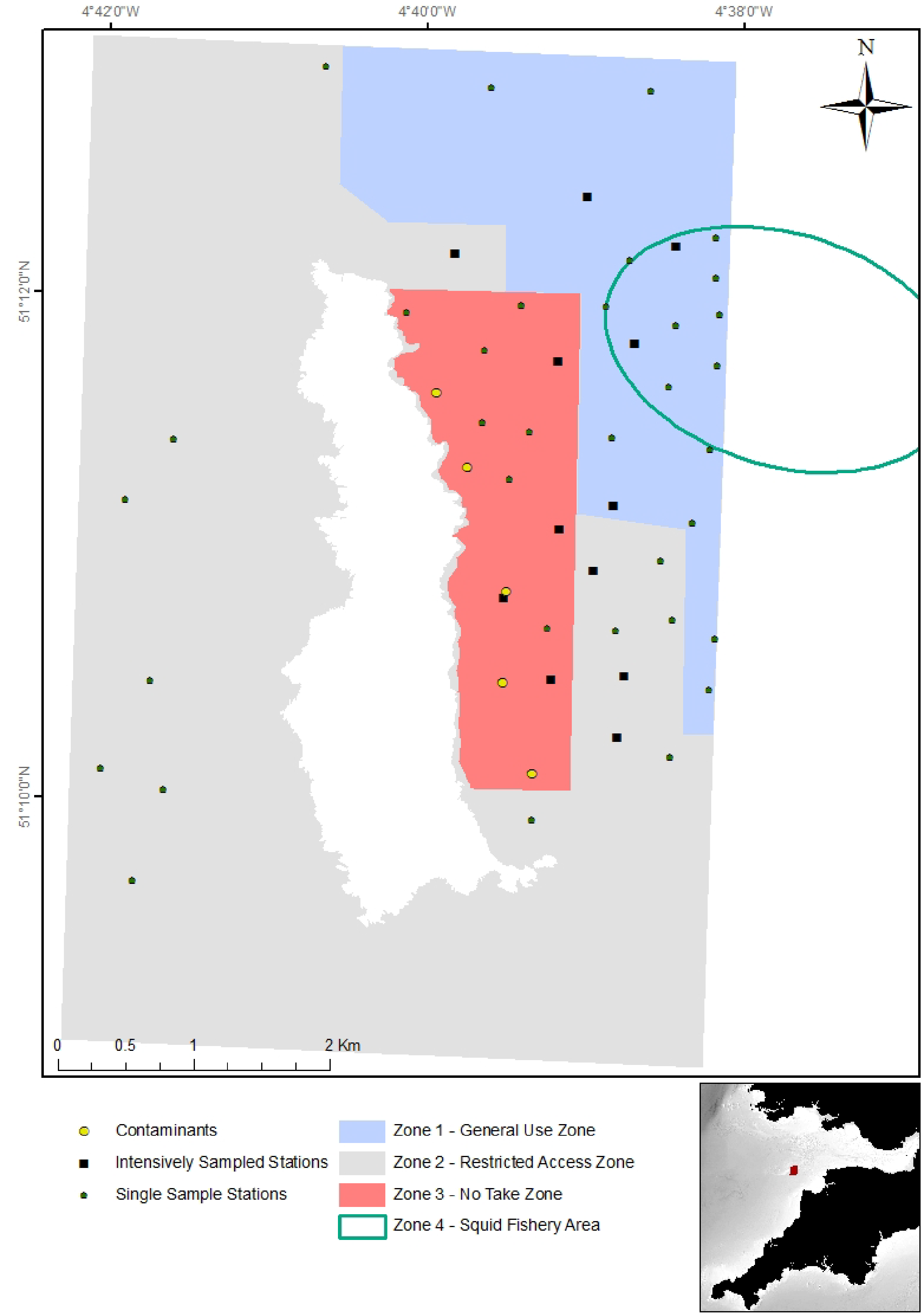

Figure 4. Locations of 2017 sediment sampling stations at Lundy SAC. The boundaries of the four fishery management zones are also displayed. Benthic data acquired from stations in Zone 4 are allocated to Zone 1 due to the lack of squid fishery activity prior in the years prior to survey (© Natural England and Cefas 2022).

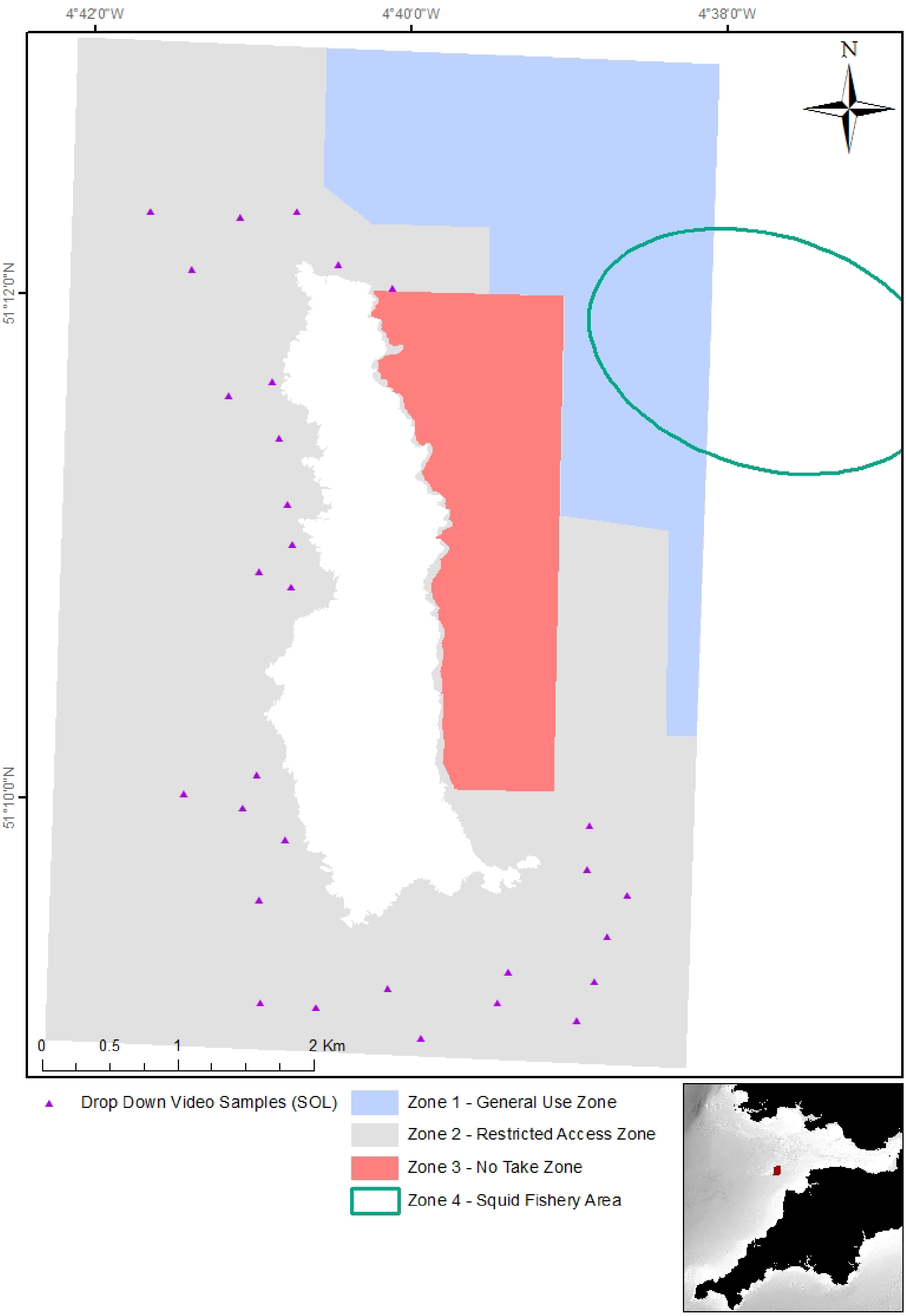

Figure 5. Locations of 30 successful DDV stations sampled at Lundy SAC in 2017, with the four fishery management zones displayed (© Natural England and Cefas 2022).

2.2 Data acquisition and processing

2.2.1 Seabed acoustic data

The raw 2015 MBES bathymetry data (see Section 1.3) were processed using CARIS HIPS. Tidal information was gathered using a CNAV 3050 DGPS receiver. Tidal height data were smoothed and extracted to reduce the tide on the bathymetry. The soundings were cleaned and smoothed using CARIS (to IHO order 1 where possible). The 2015 MBES backscatter data were processed with Fledermaus Geocoder Toolbox to produce standard and floating point (FP) geotiffs.

2.2.2 Grab sampling

The mini Hamon grab samples acquired from Lundy in 2017 ranged in sediment volume from 1.6 L to 12.8 L, with the four smallest samples (<3.0 L) being accepted for PSA only at the discretion of the lead scientist aboard the survey vessel (Arnold and Miller, 2019). The mean volume of sample (range 3.0 L to 12.8 L) processed for infauna was 6.0 L (± 0.5 L, 95% C.I.). A sub-sample (*c*500 ml) was taken from each sample and stored at -20°C prior to determining the sediment particle size distribution (PSD). Sediment samples were later processed following the recommended methodology of the North-East Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme (Mason, 2011). The less than 1 mm sediment fraction was analysed using laser diffraction and the greater than 1 mm fraction was dried, sieved and weighed at 0.5 phi (ϕ) intervals.

Following sub-sampling, the remaining sediments were sieved over a 1 mm mesh, photographed, then fixed in buffered 4% formaldehyde. These infaunal samples were subsequently processed to extract and identify all infauna present in each sample: an auditing process was adopted to ensure accurate extraction and consistent identification of all infaunal samples. Infauna were identified to the lowest taxonomic level possible, enumerated and weighed (blotted wet weight) to the nearest 0.0001 g following the recommendations of the NMBAQC invertebrate scheme component (Worsfold *et al*., 2010).

Biotopes were assigned to each of the 98 mini Hamon grab samples collected in 2017, by the primary processing laboratory, following the Joint Nature Conservation Committee (JNCC) Marine Habitat Classification methodology (Parry, 2019). It must be noted that only 12 of the 50 stations surveyed using the mini Hamon grab were intensively sampled (five replicates from each, see Objective 3 in Section 3.3). A biotope is often defined as covering an area of 5 m x 5 m, which is much larger than that afforded by a single grab sample (Connor *et al*. 2004).

The Day grab used for the retrieval of sediments for chemical analysis (nutrients and contaminants) was deployed following the Environment Agency operational instruction protocol (Environment Agency, 2007). Surface scrapes (i.e. the recently deposited sediment) were removed from each grab to a maximum depth of 1 cm (avoiding the anoxic layer). A metal scoop was used to collect material for organic content, nutrients, and organic contaminant analyses. A plastic scoop was used to sub-sample for metals, and a small corer for sediment PSA. The remaining material was then discarded. Between stations, the grab, and metal scoops were rinsed with a solvent to prevent cross-contamination of samples, as detailed in the Pollution Response in Emergencies Marine Impact Assessment and Monitoring (PREMIAM) guidelines (Law *et al*., 2011). All samples were immediately frozen on board for storage. These sediments were later analysed for the following parameters:

- Nitrogen (dry weight as N);
- Organic carbon (dry weight as C);
- Heavy and trace metals (dry weight);
- Organochlorides (Hexachlorobenzene and Hexachlorobutadiene; dry weight);
- Polybrominated diphenyl ethers (PBDEs 28, 47, 99, 100, 153, 154; dry weight);
- Polycyclic aromatic hydrocarbons (ten United States Environmental Protection Agency (USEPA) 16 compounds; Anthracene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(ghi)perylene, Chrysene + Triphenylene, Fluoranthene, Indeno(1,2,3-c,d)pyrene, Naphthalene, Phenanthrene, Pyrene; dry weight);
- Polychlorinated biphenyls (PCBs; seven congeners: 028, 052, 101, 118, 138, 153 and 180; dry weight);
- Tributyl tin (TBT; dry weight as cation).

2.2.3 Seabed imagery

Drop video camera equipment was deployed in accordance with the MESH 'Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques' (Coggan *et al*., 2007). The Subsea Technology and Rentals (STR) SeaSpyder camera system was deployed from the stern of the survey vessel. Real time navigation data acquisition and manual position fixing, when the gear contacted the seabed, was captured via Trimble® HYDROpro™ software and logged by the survey officer (no layback calculation was applied). The mid-point of the vessel's stern gantry was used as the default offset for position fixing (10.25 m from the vessels Furuno antenna (the 'origin')). Video files and digital still images were transmitted via the umbilical to be captured and saved directly to a computer in the survey cabin. The video footage was annotated with time and position using a GPS (SIMRAD MX512 DGPS) referenced video overlay (uncorrected position data). Images of the seabed were captured approximately every 10 to 15 m over a distance of *circa* 150 m (Arnold and Miller, 2019). Extra photographs were taken in heterogeneous areas of each EUNIS habitat, and where particular habitat and/or species FOCI were observed. If a habitat boundary was detected towards the end of a tow, the camera deployment was extended to confirm the change. The drop frame depth was controlled *via* a winch operator receiving instructions from the survey cabin.

2.3 Data preparation and analysis

2.3.1 Geomorphological map

The 2015 MBES bathymetry and backscatter data were used to produce a new geomorphological map for a limited area of Lundy SAC. A semi-automated approach (Object-based Image Analysis; OBIA) was utilised to segment and classify the acoustic data, based on the morphology and substrate type. A range of derivatives were also calculated from the bathymetry layer to further characterise the local variation in seabed structure. Derivatives were calculated using ESRI ArcMap 10.5 and the geoprocessing tools of System for Automated Geoscientific Analyses (SAGA) in QGIS v3.4. Although a number of derivatives were considered, the final suite of layers and scales used (Table 4) in both the segmentation or classification were determined based on visual assessment of the bathymetry and the derivative layers produced, in line with current best practice for the identification and classification of seabed morphologies (Dove et al., 2020). A multiresolution segmentation algorithm was then applied in eCognition v9.3.5. This segmentation iteratively merges pixels into image-objects until the homogeneity criterion is reached (termed the 'scale parameter') incorporating limitations based on object shape (compactness and shape parameters). The optimal parameters and weightings were determined through an iterative process by visually assessing different segmentations to find the settings which most closely reflected real world objects, again in line with current best practice for seabed morphological mapping.

Table 4. Bathymetric derivative layers used in the segmentation and classification of the 2015 MBES data for Lundy SAC (© Natural England and Cefas 2022).

Derivative	Description
Bathymetry Position Index (5-10; 10-20; 40-50)	Vertical position of cell relative to neighbourhood (identifies topographic peaks and troughs). Calculated with two neighbourhood sizes of 5-10, 10-20 and 40-50 cells (inner and outer annulus respectively) to capture topographical elevation at different spatial scales (Weiss, 2001). Positive values represent features higher than surrounding area and negative values represent lower features, and values near zero are either flat or areas of constant slope
Standardised height	First normalised height is calculated, which considers the extension of a catchment area of a specific terrain point. Normalised height allots a value of 1 to the highest and value 0 to the lowest position within a respective reference area.

Derivative	Description
	Standardised height is the product of normalised height multiplied with absolute height (Dietrich and Böhner, 2006)
Slope	The incline, or steepness, of a bathymetric surface. Measured in degrees from the horizontal. The slope for a cell in a raster is the steepest slope of a plane defined by the cell and its eight surrounding neighbours
Aspect	Aspect identifies the downslope direction of the maximum rate of change in value from each cell to its neighbours. It can be thought of as the slope direction. The values of each cell in the output raster indicate the compass direction that the surface faces at that location. It is measured clockwise in degrees from 0 (due north) to 360 (again due north), coming full circle. Flat areas having no downslope direction are given a value of -1

An initial segmentation was applied, based on bathymetry and a scale parameter of 10.0, with compactness and shape of 0.0 and 0.3, respectively. The second stage of the mapping process used those arithmetic and geometric properties of the various derivative layers (known as 'features'); which best fit the data to classify the objects into expected geomorphic types. A manually determined hierarchical set of rules and expert judgement, in line current best practice for geomorphological mapping, was created based on the above-described features, and used to classify all objects into six geomorphic classes (described in Table 5). This process is described in further detail in Appendix 2. This coarse subdivision permitted classification of the substrate without the risk of overinterpretation of the data, while still giving valuable information on the morphology of the seabed. A seventh class was used to isolate a shipwreck.

Table 5. Geomorphic classes used to broadly classify the mapped areas within Lundy SAC, based on MBES data acquired in 2015 (© Natural England and Cefas 2022).

Geomorphic Class	Description
Bedrock or sub-cropping rock	Well-layered succession of shale beds, trending approximately E-W, gently folded and fractured, in the southern part of the mapped area. Possible sub-cropping rock (bumpy and irregular seabed) in the north-western part of the mapped area
Sandbank	Broad and flat-topped sediment bank which occupies a large portion of the mapped area. Only the western contour is visible, while the eastern side is outside the acoustic data
Rippled sediment	Large (>1 m) sedimentary structures that indicate sediment agitation by water current or waves (or wind). They consist of repeating wavelike forms with symmetrical/asymmetrical

Geomorphic Class	Description
	slopes, sharp peaks, and rounded troughs, and occur in the northern portion of the map or on the sandbank
Irregular seabed	Irregular and gently sloping seabed that does not fall within any of the other classes
Incision	Deep scour in the sandbank sediment caused by the presence of the shipwreck
Shipwreck	A shipwreck in the mapped area

2.3.2 Sedimentological map

To predict the sediment PSA across the acoustic data region, the 2017 PSA data were linked to the 2015 MBES data and derivative layers, to find correlations between grain size and acoustic and physical properties. The temporal mismatch of the two datasets introduces an unaccountable error, for example due to natural sediment migration during this period. The resulting sediment map should, therefore, be considered as a general indicator of sediment size distribution. PSA data collected in 2012 from just six stations within the area of the 2015 MBES data were additionally used. While the limited number of samples renders the 2012 data unsuitable for the construction of a separate sediment prediction model, a qualitative comparison between the two PSA datasets was conducted and the outcomes used to assess the validity of the predicted 2017 sediment extent.

A selection of layer attributes, including summary and textural statistics, were calculated for objects obtained from an *ad hoc* segmentation (applied on Bathymetric Position Index; BPI10-20 (weight 1.0) and aspect (weight 0.3) with a scale parameter of 75.0, slope of 0.0 and a compactness of 0.5). Where groundtruth sample stations overlapped with the MBES area, objects were classified based on the assigned EUNIS habitat class of the sample. A total of 48 objects overlapped the MBES data used for mapping. Prior to modelling, samples were separated into training and testing datasets (70 / 30 %) using random sampling with proportional allocation based on class type (Olofsson *et al*., 2014).

Objects belonging to the geomorphic class ‘bedrock and subcrop’ and ‘shipwreck’ were transferred directly from the geomorphological map. A random forest model was calculated based on the decrease in node impurity weighted by the probability of reaching that node (Table 6). Mean depth values, the standard deviation of backscatter, and the standard deviation of BPI40-50 were the most useful physical attributes to discriminate the sediment distribution, together with the Gray-Level Co-Occurrence Matrix (GLCM) Entropy. The mean backscatter (7^{th} position) and other MBES derivatives (e.g. aspect, slope) were less useful in the model.

Table 6. Random forest model (based on feature importance) list for the top 10 features, as measured by the decrease in node impurity weighted by the probability of reaching that node (© Natural England and Cefas 2022).

Feature	Importance score
Mean seabed depth	0.10
Std. Dev. backscatter	0.10
Std. Dev. BPI40-50	0.10
GLCM texture (Entropy)	0.09
GLCM texture (Dissimilarity)	0.08
Std. Dev. aspect	0.08
Mean backscatter	0.07
GLCM texture (Contrast)	0.07
GLCM texture (Homogeneity)	0.06
Mean slope	0.06

Three EUNIS sediment types (‘A5.1 Sublittoral coarse sediment’, ‘A5.4 Sublittoral mixed sediments’ and ‘A5.2/A5.3 Sublittoral sand/Sublittoral mud’) were modelled using the random forest algorithm within the *scikit-learn* package in Python (Pedregosa *et al*., 2011). Random forest is a machine learning algorithm that uses tree-type classifiers and bootstrap aggregation based on subsets of the input data (Breiman, 2001). Hyperparameters for the optimal number of features randomly selected at each split (max_features), and the optimal number of trees within models (n_estimators) were assessed using a random search cross-validation in *scikit-learn*. Model parameters n_estimators and max_features were then set to 1000 and 'auto' respectively. A total of 14 predictor variables were included in the model. The predictive accuracy was tested by constructing an error matrix and calculating the overall predictive accuracy.

2.3.3 Sediment particle size distribution

Sediment particle size distribution data (half phi classes) were grouped into the percentage contribution of gravel, sand, and mud derived from the classification proposed by Folk (1954). Each sample was assigned to one of three sediment Broadscale Habitats (BSH) using a modified version of the classification model produced during the Mapping European Seabed Habitats (MESH) project (Long, 2006). In addition, the full resolution PSA data were grouped using EntropyMax, a non-hierarchical clustering method that summarises large matrices of PSD datasets into a finite number of groups (Stewart *et al*., 2009), using the Calinski-Harabasz statistic (Orpin and Kostylev, 2006).

2.3.4 Infaunal data preparation

The infaunal data were checked to ensure consistent nomenclature, and identification policies against the World Register of Marine Species (WoRMS[7]). Discrepancies were resolved using expert judgement following the truncation steps presented in Appendix 3.

2.3.5 Epibiota data preparation

Imagery data were acquired in the form of high definition (HD) videos and still images from 33 transects. Due to high turbidity, only eight of the transects possessed seabed video data of sufficient quality for analysis. However, still images from 30 of the transects were of sufficient quality to be analysed, resulting in percentage cover and abundance matrices from 445 still images.

The video data from each of the eight transects were divided into segments based on observed boundaries between EUNIS Level 4 classes. This resulted in a total of 19 video segments with EUNIS Level 5 classes. Owing to the limited number and distribution of the analysed video segments, further analyses to address report Objective 1 were undertaken solely on the still imagery data. Still images were first filtered for quality, with 238 images of ‘Good’ or ‘Excellent’ quality (Turner *et al.*, 2016) being selected. Additionally, 121 images of ‘Poor’ or ‘Very Poor’ quality were included. These poorer quality images were included due to an identified bias in quality classification, which, led to stills that were obscured by the kelp canopy being labelled as ‘Poor’ or ‘Very Poor’, thus disproportionately reducing the prevalence of kelp taxa within the still images.

The raw matrices (abundance/count and percentage cover) were truncated as described in Appendix 4. As a single still image cannot constitute a sample owing to limited and varied fields of view, a process of sub-segment generation was undertaken on the truncated data matrices (after Downie *et al.*, 2020). Sub-segments were created by combining percentage cover data from geographically adjacent still images of equivalent EUNIS Level 3 habitats. A varying number of still images were combined to result in 40 sub-segments, with an average combined field of view (FoV) of 0.57 m^2 (sd = 0.32 m^2) of seabed. Two of the defined sub-segments included non-geographically adjacent stills, while four contained two EUNIS Level 3 habitat types. As such, these six were discarded from the resulting sub-segment matrix for epifaunal assemblage analysis. This resulting matrix of 56 sub-segments contained average percent cover values for the truncated taxa, generated from 359 still images.

[7] http://www.marinespecies.org/

2.3.6 Annex I Reef assessment

A full investigation of Annex I Reef stony reef subtype was not possible (i.e. a full assessment according to Irving (2009)) due to the lack of available information on elevation/relief and total extent of stony reef features (due to lack of video data). However, a broad analysis of stony reef was undertaken using still image substrate composition data.

This assessment focused on determination of 'bedrock' or 'stony' reef subtype, as far as is possible from individual still images (the video quality was too poor to analyse), after the method proposed by Duncan and Pinder (2019). As average substrate percentages were derived from ~4 still images (which comprised a sub-segment), the 100 % threshold for classification of a bedrock reef (i.e. with a correlated 'reef' type biotope) was applied to the maximum (not to the mean) across all component still images. As such, a sub-segment was classified as the Annex I Reef subtype 'bedrock' if at least one of the component images had a bedrock percentage of 100 % (Figure 6). The threshold value to classify a sub-segment as the 'stony reef' subtype was an average (summed) cobble and boulder proportion of >40 %. Any segments which were composed of between 40 and 99 % bedrock and <40 % cobbles and boulders were classified as 'bedrock and/or stony reef (potential)' (after Duncan and Pinder, 2019).

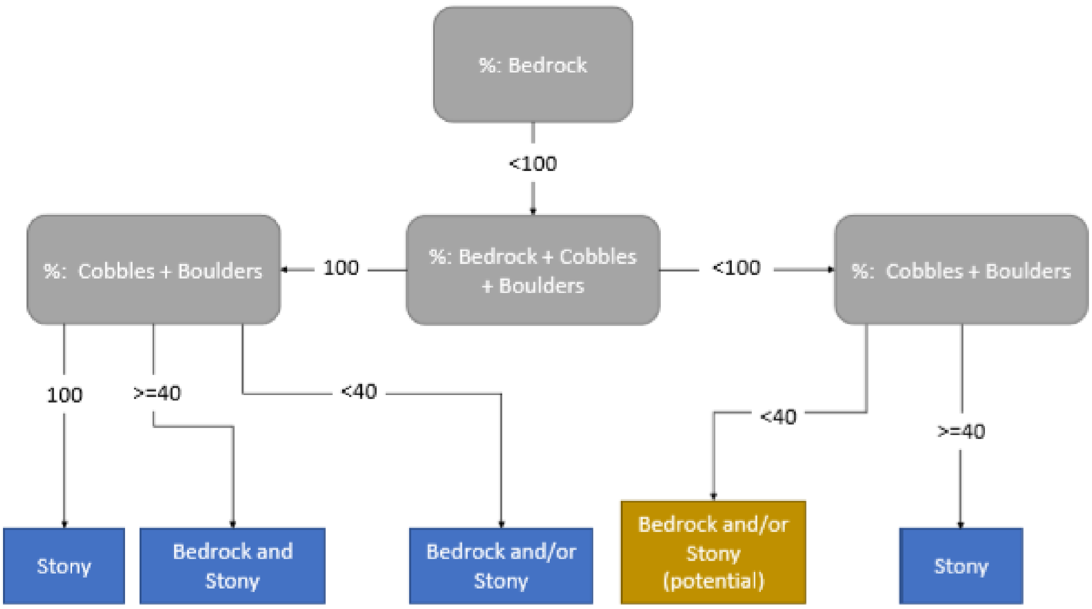

Figure 6. Decision tree classification of reef subtype from substrate percentages of records with correlated biotopes assigned. Taken from Duncan and Pinder (2019).

2.3.7 Non-indigenous species (NIS)

The presence of non-indigenous species (NIS) in sediment samples collected in 2007, 2012, and 2017 (from 50, 17 and 50 stations respectively), and in seabed imagery collected in 2017, was determined by cross-referencing the taxon recorded in each survey dataset with NIS which have been selected for assessment of Good Environmental Status in GB waters under Marine Strategy Framework Directive (MSFD) Descriptor 2 (Stebbing *et al*., 2014). Additional taxa listed as NIS in the JNCC 'Non-native marine species in British waters: a review and directory' report by Eno *et al*. (1997), which have not been selected for assessment of Good Environmental Status in GB waters under the MSFD, were also cross-referenced to further understand the presence of NIS in the sedimentary habitats of the Lundy SAC. See Annex 2 for the complete list of NIS assessed.

2.3.8 Tidal modelling

Maximum (peak ebb and peak flood) tidal current velocities (m s^{-1}) at the seabed were predicted using a tidal model built for the Lundy SAC. The depth-averaged model for Lundy SAC is nested within a larger English Channel model (which extends into the Bristol Channel) and has been built using an unstructured triangular mesh, using the software Telemac2D (v7p1). The model domain extends 48.01°N to 52.48°N and 2.23°E to 9.51°W. The unstructured mesh was discretised with 292, 630 nodes and 571, 260 elements. The mesh has a resolution of approximately 3 km along the open boundary. In the area of interest, the resolution was refined to approximately 25 m. Bathymetry for the model was sourced from the Defra Digital Elevation Model (Astrium, 2011). The resolution of the dataset is 1 arc second (~30 m). The hydrodynamics are forced along the open boundaries using 11 tidal constituents (M2, S2, N2, K2, K1, O1, P1, Q1, M4, MS4 and MN4) from the OSU TPXO European Shelf 1/30° regional model. After a spin up period of 5 d, the model was run for 30 d to cover a full spring-neap cycle.

2.3.9 Numerical and statistical analyses

2.3.9.1 Infaunal species and community analysis

The composition and variation of infaunal assemblages associated with each EUNIS Level 3 class was assessed based on the data from the grab samples collected in 2017 (report Objective 1; see Table 3 for the list of feature attributes and supporting processes addressed for Objective 1). A sub-set of these samples was used to generate datasets for use in report objectives 3, 4 and 5 (refer to Figure 4 showing the distribution of samples across the survey area and the fisheries management zones in which they are located).

Highly variable taxon counts were down-weighted in the infaunal matrices using a dispersion weighting (Clarke *et al.,* 2006) within Primer v7 (Clarke and Gorley, 2015) and Bray-Curtis similarity matrices were produced from the square root transformed data for both samples and variables. Non-metric multidimensional scaling ordinations (nMDS) were produced for the infaunal data to illustrate differences in assemblage structure within and between *a priori* group classifications (e.g. EUNIS class). The Analysis of Similarity (ANOSIM) routine was used to determine any significant differences in infaunal assemblage composition between groups and the Similarity Percentage (SIMPER) routine was used to highlight the taxa contributing to within-group similarity (Clarke and Warwick, 1994).

Infaunal assemblages were derived using a non-hierarchical 'k R Clustering' method whereby the optimum number of groups within the data set was determined using the ANOSIM R statistic to provide a value for k-group division and the Similarity Profile (SIMPROF) algorithm was used to test whether a suitable number of groups had been reached (Min. 2; Max. 20). This non-hierarchical clustering approach enables samples to be reallocated at latter points in the clustering process without becoming isolated as similarity measures are developed during algorithm computation (Clarke, Somerfield and Gorley, 2016).

Several univariate metrics of community structures considered relevant to describe the basic assemblage attributes were generated using the DIVERSE routine in Primer v7 for each sample (together with total biomass to reflect assemblage function):

- species richness (*S*): number of taxa present in a sample;
- abundance (*N*): the total number of individuals of enumerable taxa. Colonial taxa are recorded as present and subsequently assigned an abundance of 1;
- Pielou's evenness (J') $\frac{H'}{\ln{(S)}}$: where H' is the Shannon Weiner diversity; shows how evenly the individuals in a sample are distributed. J' is a range of zero to one. The less dominance of a taxa in the sample, the higher J' is, and;
- total biomass (*g*): the summed mass of all enumerable taxa; blotted wet weight. Taxa were removed from the dataset before the calculation of total biomass if they (i) contributed to ~20 % of the total biomass at the site and (b) possessed an average biomass per individual of greater than one gram. Eleven taxa were removed according to this approach as they dominated the recorded biomass within a sample but are not reliably sampled using a grabbing device.

Differences in univariate metrics between *a priori* groups were tested using non-parametric one-way analysis of variance on ranks (Kruskal-Wallis) which returns a test statistic 'H' and a probability value p. Pairwise comparisons using the Wilcoxon rank sum test were carried out if 'H' was significant. A result was deemed to be statistically significant when $p < 0.05$. Mean values of each univariate metric for each *a priori* group (e.g. EUNIS class, Zone, intensively sampled box; depending on report objective) were plotted with their associated 95 % confidence intervals using ‘ggplot2’ and ‘psych’ packages in R (Wickham, 2016; Revelle, 2019; RStudio Team, 2019).

To compare the variability observed in sediment particle size distribution and infauna between the intensively sampled box and the wider spatial (single sample) approach for report Objective 5, the coefficients of variation (CoV) of mud, sand and gravel (for sediment particle size) and univariate metrics of community structure and total biomass were compared. The CoV is a statistical measure of the dispersion of data around the mean and thus represents the ratio of the standard deviation to the mean. As a result, the CoV is a useful statistic for comparing the degree of variation from one data series to another, even if the means are markedly different from one another. The MBESS package in R was used to calculate CoV and associated confidence intervals using a non-central t-distribution (Kelley, 2019).

2.3.9.2 Epibiotic species and community analysis

The epibiotic percentage cover data were analysed to address report Objective 1, aiming to describe the biological characteristics of the rocky substrate EUNIS classes. The presence and percentage cover of both macroalgal and macro(epi)faunal taxa were included as part of this assessment. The sub-segmented percent cover matrix based on the still images was initially entered into R (R Development Team, 2019) and averaged across sub-segment membership, and dispersion weighted using the ‘decostand’ function in the ‘vegan’ package (Oksanen *et al*., 2019).

A Bray-Curtis similarity matrix was generated from the transformed dataset, and an nMDS ordination was generated to investigate differences in the assemblages between EUNIS classes. A one-way ANOSIM test was then performed to test for differences in assemblage composition between EUNIS classes.

K-means clustering was then used to separate the averaged dispersion weighted similarity matrix into distinct, ecologically meaningful, clusters using the ‘cascade’ function within the ‘vegan’ package. This function allows users to set the minimum (2) and maximum (20) number of partitions expected within the data. Multiple partitions are created, forming a cascade from small to large numbers of non-hierarchical partitions, as determined by a k-means algorithm. The optimal number of clusters was determined using the Calinski-Harabasz criterion (Caliński and Harabasz, 1974). This approach differs slightly from the Primer k-R clustering routine used to separate the infauna samples into clusters as the ‘cascade’ function in the R ‘vegan’ package provides for more varied, and thus more epibiotic (i.e. ground-cover) appropriate k-means error measurements (i.e. Calinski-Harabasz and Simple Structure Index (SSI) criteria), than available in Primer 7 (Legendre, P. Legendre, 2018).

To define the habitat classes more clearly, the clusters derived from the multivariate analysis were then interrogated for characterising taxa using the Multi-level Pattern analysis routine of the R package ‘indicspecies’ (De Caceres *et al*., 2010). This is a permutational testing routine which permutes input clusters and compares these combinations against presence of the taxa of each seabed type in the raw matrix, using the Indicator Value index (IndVal) as a test statistic (Dufrêne and Legendre, 1997) to measure association between individual taxa and clusters. This statistic was developed for percentage cover (ground cover) of vegetation taxa and is thus considered to be a more appropriate metric for epibiotic assemblages determined from still imagery. For each taxon, the routine selects the combination with the highest association value per cluster. The patterns which best match are tested for statistical significance (permutational testing) of the associations, providing the overall IndVal test statistic, its components (‘IndVal A’ and ‘IndVal B’) and a p value for each taxon within each cluster. Higher test statistics indicate greater value of the taxa as an indicator of that cluster. Component ‘A’ of the IndVal index refers to the probability of the sample belonging to the cluster, given that a certain taxon has been found (the *specificity*, or the power of that taxon to predict a cluster). Component ‘B’ (the *fidelity*) is the probability of finding the taxon in samples belonging to that cluster (De Caceres *et al*., 2010). Finally, the resulting clusters and sub-clusters were analysed using the SIMPER routine in Primer v7 to allow the contributing taxa of each cluster group to be investigated in greater detail.

3 Results

This report sets out to address ten objectives, the results pertaining to each objective are presented in the following sub-sections.

3.1 Objective 1

Provide a description of the extent, distribution, structural and (where possible) functional attributes, and the supporting processes, of the designated features within the site, to enable subsequent condition monitoring and assessment.

3.1.1 Tidal regime: energy and exposure

Modelled peak ebb and flood tidal current magnitudes within the Lundy SAC varied between 1.02 m s^{-1} (Figure 7) and 0.88 m s^{-1} (Figure 8), respectively. The highest magnitudes are observed off the NW and SE coasts of Lundy at peak ebb tide, and off the SW of the island at peak flood tide. Tidal current directions at peak ebb and peak flood vary significantly across the site, with diffraction around Lundy resulting in the presence of large tidal eddies. Within the Lundy SAC this diffraction manifests in the peak tidal flow directions along the east and west coasts being toward the island (at comparatively low magnitudes) at both peak ebb and peak flood.

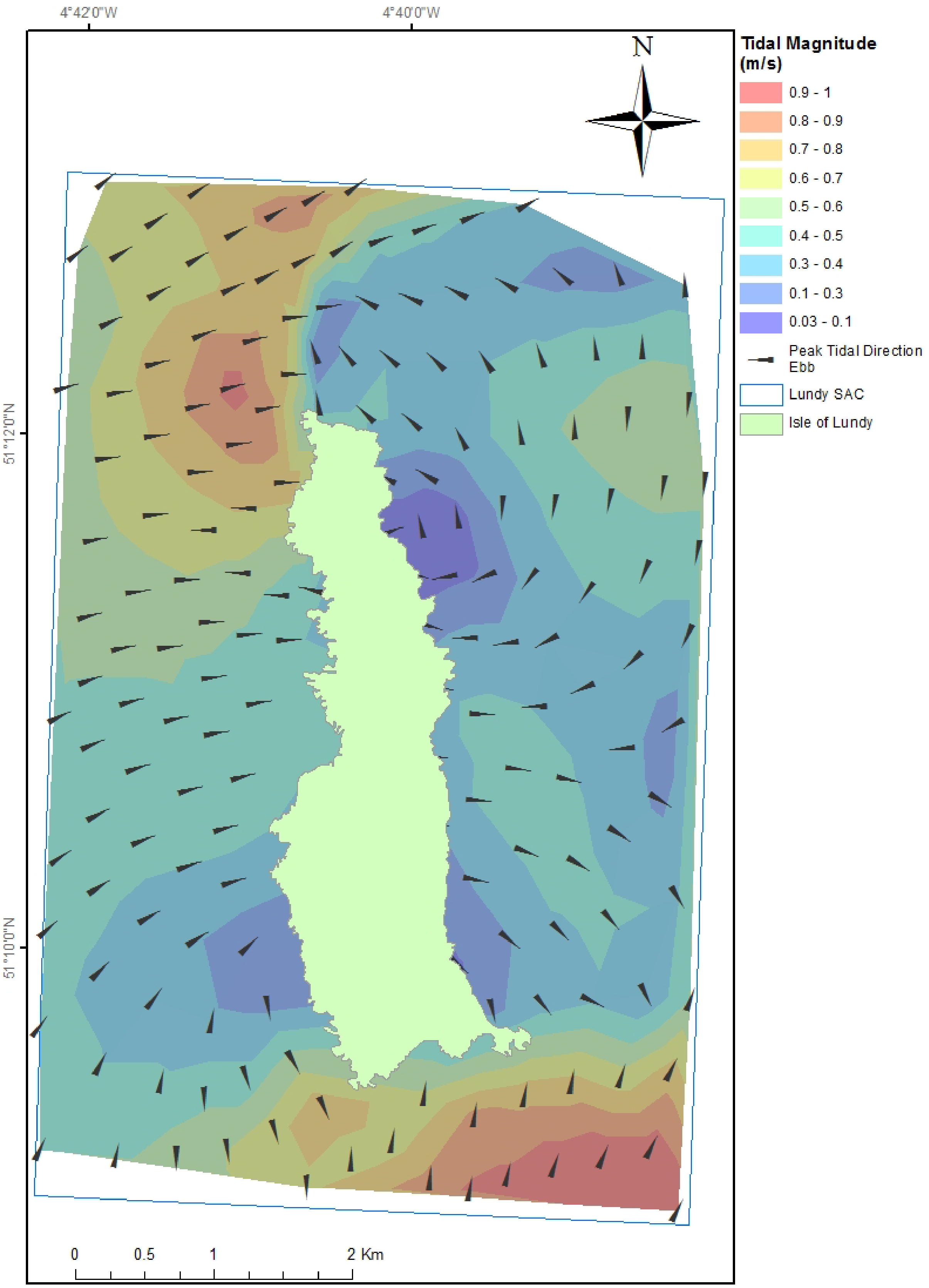

Figure 7. Direction and magnitude of peak tidal ebb flow within the Lundy SAC (© Natural England and Cefas 2022).

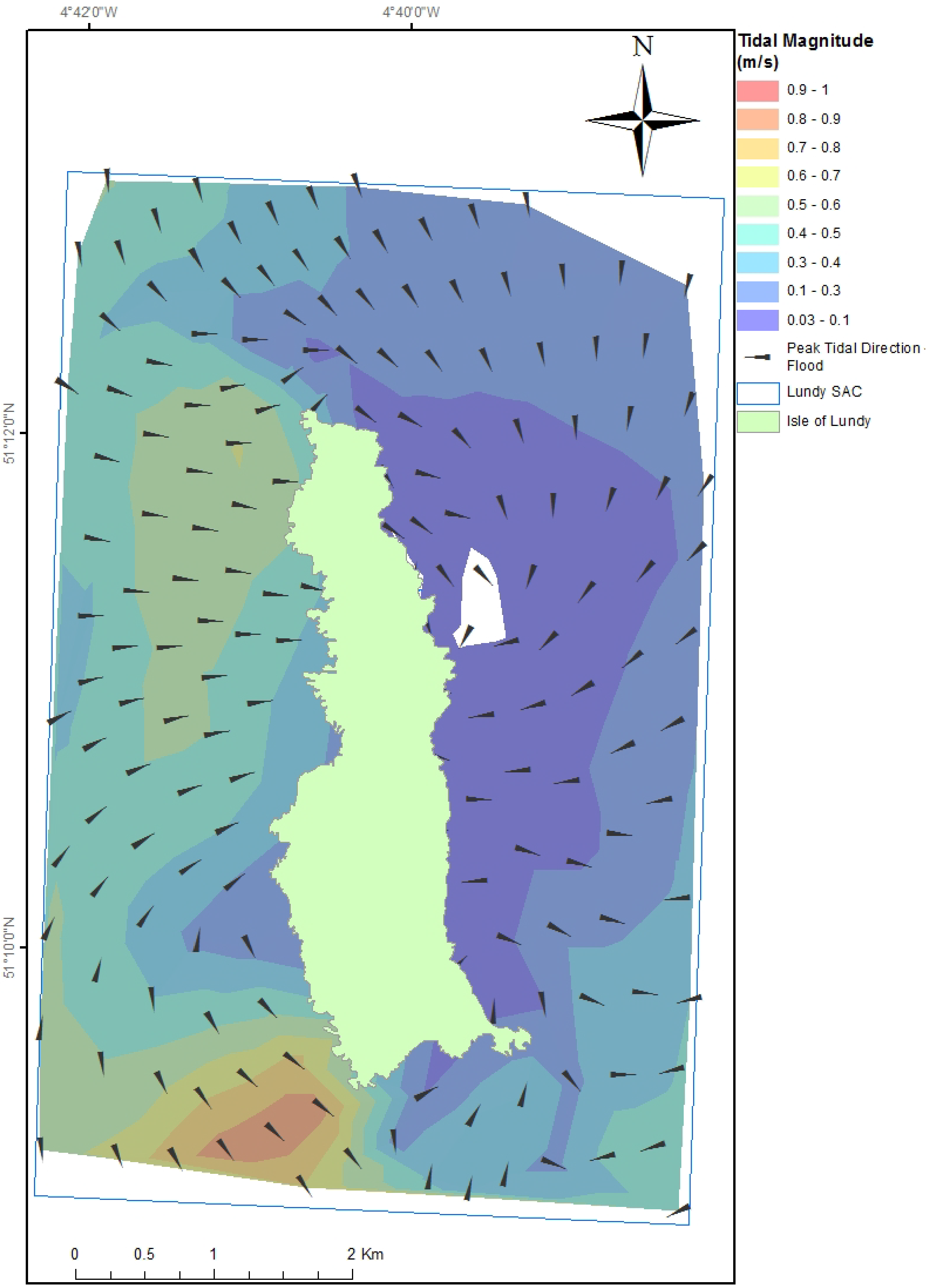

Figure 8. Direction and magnitude of peak tidal flood flow within the Lundy SAC (© Natural England and Cefas 2022).

3.1.2 Particle size analysis

The 98 sediment samples analysed for PSA were classified as four EUNIS habitat classes: ‘A5.1 Sublittoral coarse sediment (41 samples); ‘A5.2 Sublittoral sand’ (15 samples); ‘A5.3 Sublittoral mud’ (8 samples); and ‘A5.4 Sublittoral mixed sediments’ (34 samples) (Figure 9). However, as many of the samples located in the sediment trigon (Figure 9) are close to the delineation between these classes, the sediments of many of the stations are not necessary markedly dissimilar.

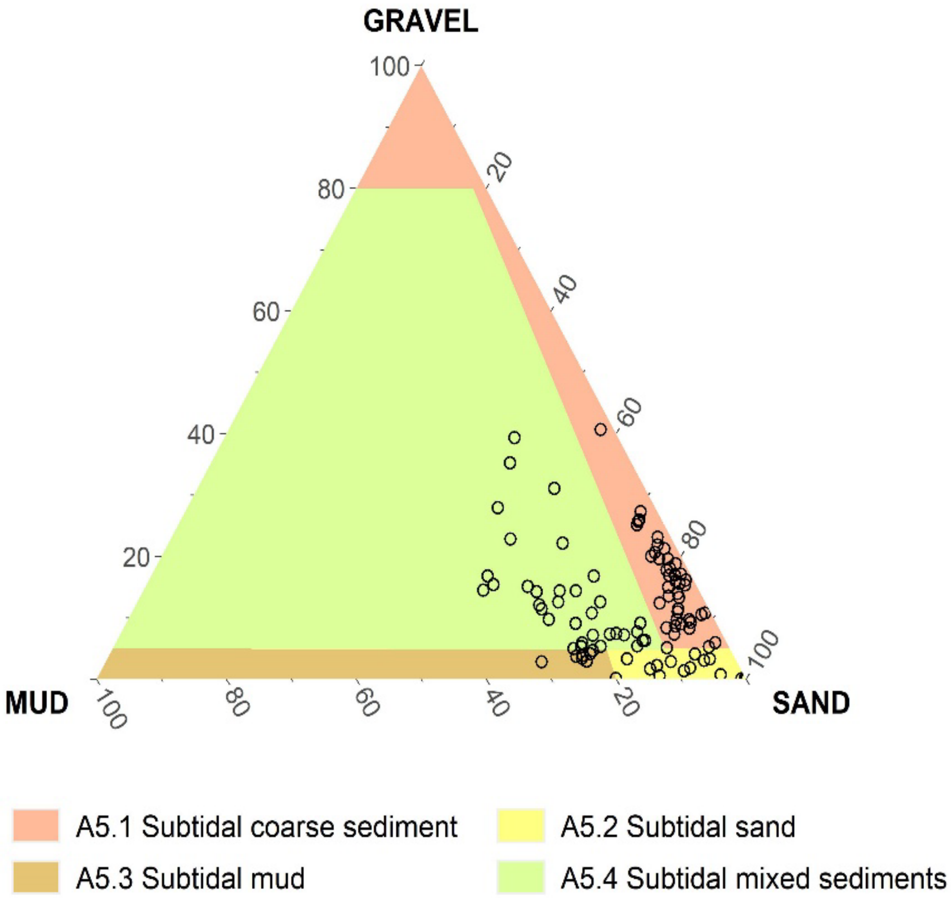

Figure 9. Classification of 2017 sediment PSA data (half ϕ) from Lundy SAC into EUNIS habitat classes (coloured areas) plotted on a true scale subdivision of the Folk triangle into the simplified classification for UKSeaMap (Long, 2006; Folk, 1954) (© Natural England and Cefas 2022).

The map of these EUNIS classes (Figure 10) indicates that ‘A5.1 Sublittoral coarse sediment’ is predominantly found to the northeast of Lundy, while ‘A5.4 Sublittoral mixed sediments’ (the next most common class in the grab sample dataset) is generally limited to the east of Lundy. It is in this region where the eight samples classed as ‘A5.3 Sublittoral mud’ are located. Finally, the 15 samples of ‘A5.2 Sublittoral sand’ are more widespread, being located to the west, north and the east of Lundy (Figure 9). With the 2017 PSA data overlaying the 2020 Open Data Habitat Map (Natural England, 2020) it can be seen that there is an evident lack of agreement in extent of the habitat class ‘A5.4 Subtidal mixed sediments’ – this habitat is not predicted by the Open Data Habitat Map.

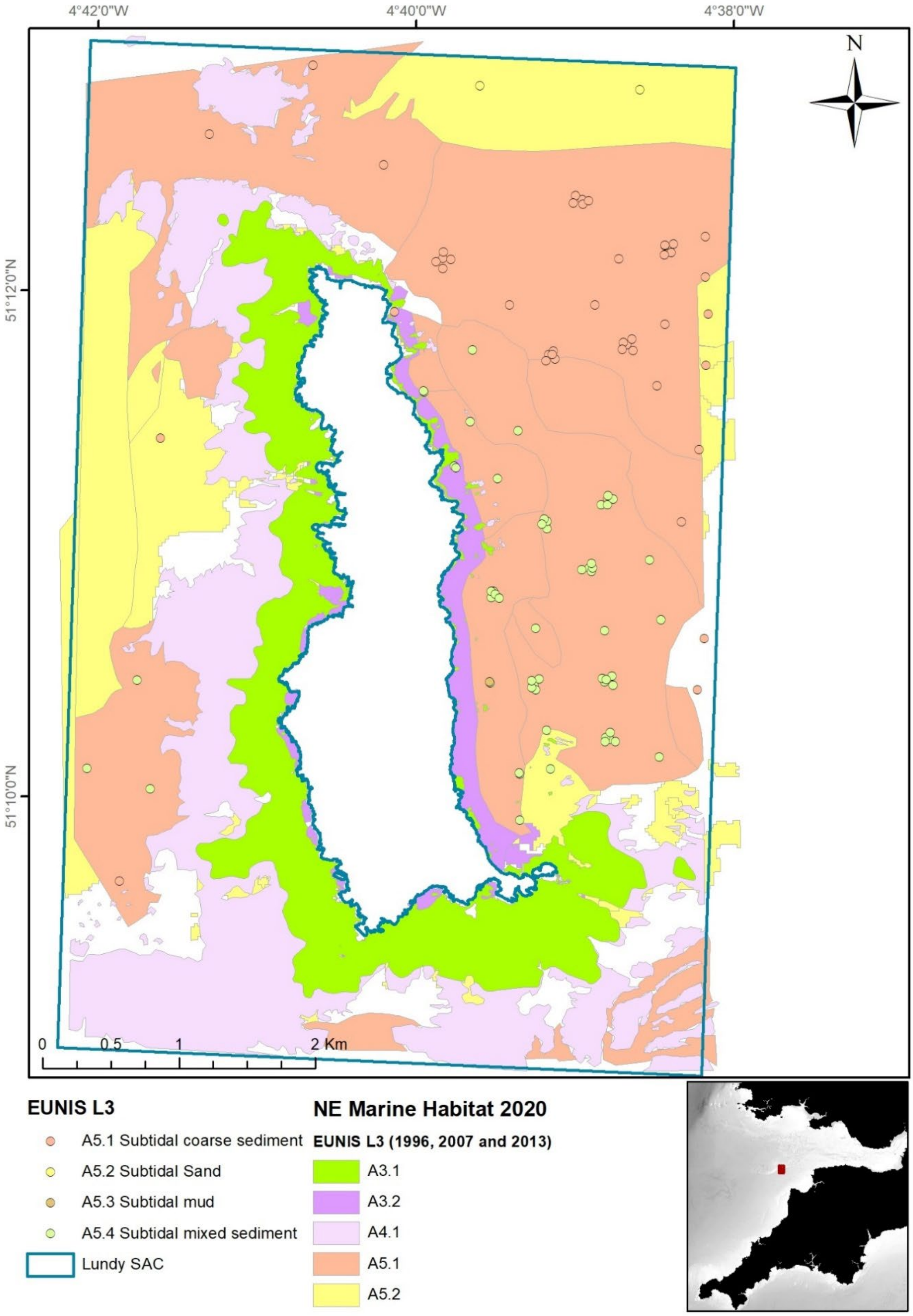

Figure 10. Distribution of stations coloured according to EUNIS class based on Folk (1954) as determined by 2017 sediment PSA data from Lundy SAC. Points overly the 2020 Open Data Habitat Map (Natural England, 2020) (© Natural England and Cefas 2022).

EntropyMax based on the PSA data from the 98 samples resulted in five sediment groups (one forming two sub-groups); while the delineations between these groups show some relationship with EUNIS habitat class based on Folk (1954), some divergences are apparent (Figure 11). The samples that were classed as ‘A5.4 Sublittoral mixed sediments’ were categorised into two Entropy cluster groups: groups 1 and 2a. While both groups represent very poorly sorted gravelly, muddy sand, samples in group 1 possess higher fractions of both gravel and silt/clay than those of group 2a and a lower sand content (Table 7). Meanwhile, samples of group 2b (very poorly sorted slightly gravelly, muddy sand; Table 7) were separated into three BSHs according to the Folk (1954) approach.

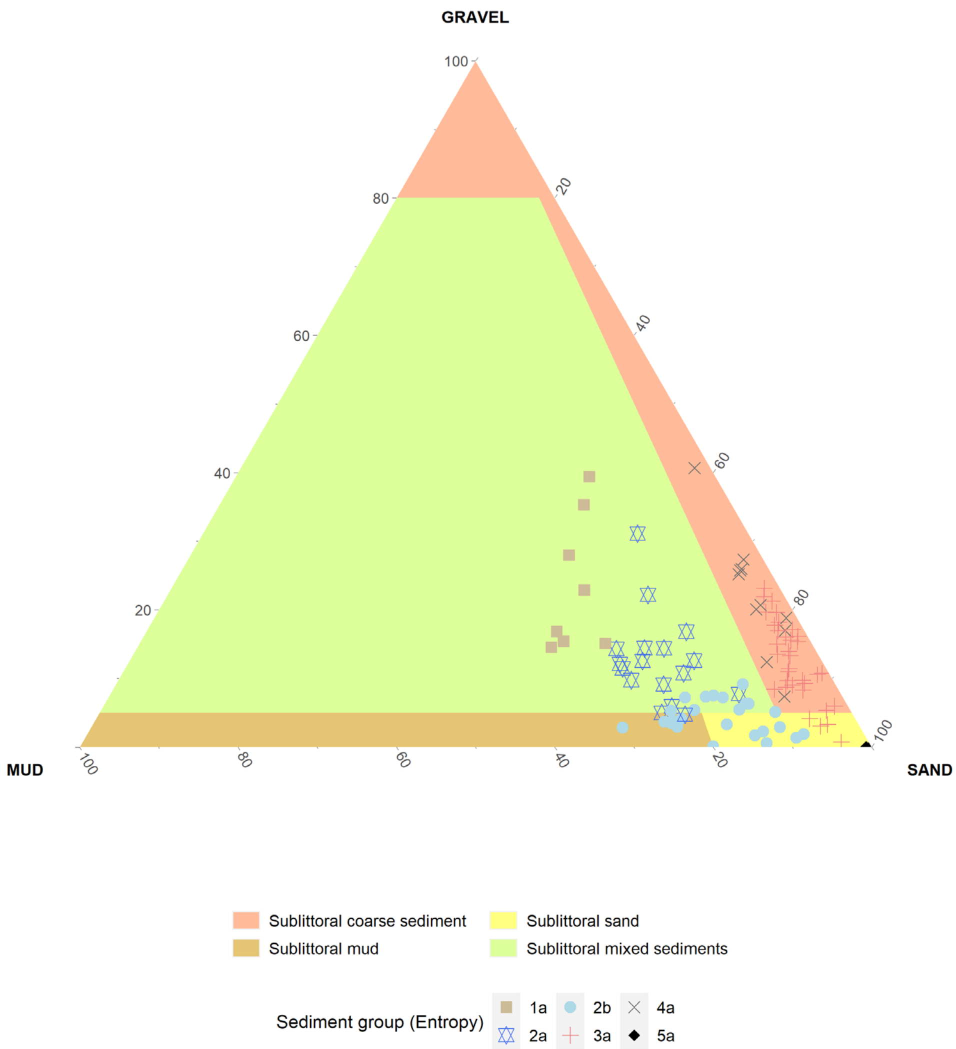

Figure 11. Classification of 2017 sediment PSA data (half ϕ) from Lundy SAC into Entropy groups, displayed over EUNIS habitat classes (coloured areas) (Long, 2006; Folk, 1954) plotted on a true scale subdivision of the Folk triangle into the simplified classification for UKSeaMap (© Natural England and Cefas 2022).

Table 7. Sediment summary and description of the Entropy groups derived based on the 98 sediment samples across the Lundy SAC in 2017 (© Natural England and Cefas 2022).

Entropy group	Number of samples	Sediment description	Sorting description	Gravel (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)	Silt/clay (%)	EUNIS habitat
1a	8	Gravelly Muddy Sand	Very poorly sorted	23.28	16.33	8.68	7.72	10.48	6.83	26.68	'A5.4 Sublittoral mixed sediments'
2a	17	Gravelly Muddy Sand	Very poorly sorted	12.66	8.54	11.13	17.50	20.72	7.77	21.69	'A5.4 Sublittoral mixed sediments'
2b	25	Slightly Gravelly Muddy Sand	Very poorly sorted	4.31	4.40	10.43	27.87	28.99	7.08	16.91	'A5.2 Sublittoral sand'
3a	11	Gravelly Sand	Very poorly sorted	21.94	9.82	20.74	28.58	13.54	1.51	3.87	'A5.1 Sublittoral coarse sediment'
4a	34	Gravelly Sand	Poorly sorted	12.48	6.34	16.81	32.03	25.36	3.41	3.56	'A5.1 Sublittoral coarse sediment'

Entropy group	Number of samples	Sediment description	Sorting description	Gravel (%)	Very coarse sand (%)	Coarse sand (%)	Medium sand (%)	Fine sand (%)	Very fine sand (%)	Silt/clay (%)	EUNIS habitat
5a	3	Slightly Gravelly Sand	Moderately well sorted	0.07	0.17	35.42	58.77	5.34	0.00	0.23	‘A5.2 Sublittoral sand’

Spatially, the distribution of the Entropy groups shows a common pattern to that observed for EUNIS habitat class (Figure 12). The northeast region off Lundy which was dominated by ‘A5.1 Sublittoral coarse sediment’ is occupied by group 3a (very poorly sorted gravelly sand) and some samples from 4a (poorly sorted gravelly sand). Meanwhile, the area south of this represented by ‘A5.4 Sublittoral mixed sediments’ and ‘A5.3 Sublittoral mud’ is classed as Entropy groups 1a (very poorly sorted, gravelly muddy sand) 2a and 2b (very poorly sorted, gravelly and slightly gravelly muddy sand, respectively). Thus, the Entropy approach provides an alternative, albeit related, insight into the distribution of sediments across the Lundy SAC with a subtle increase in detail.

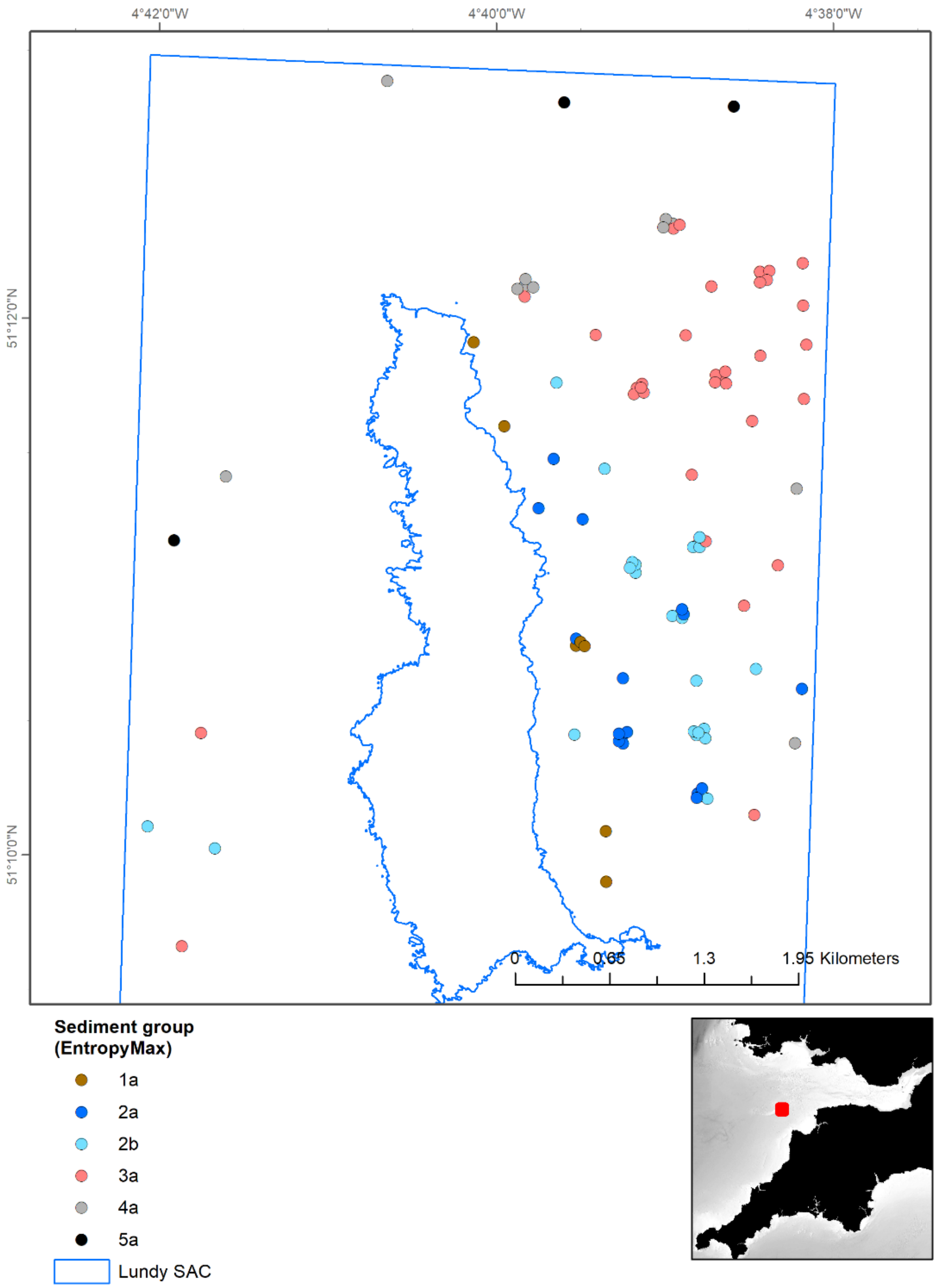

Figure 12. Distribution of the sediment clusters derived by EntropyMax based on the 2017 sediment samples taken from Lundy SAC (© Natural England and Cefas 2022).

3.1.3 Infaunal community analysis

3.1.3.1 Univariate metrics and biomass of infaunal assemblages across the Lundy SAC

A total of 472 taxon records remained following truncation of the infaunal abundance data from the 98 grab samples collected in 2017. This included 283 annelid taxa, 152 arthropod taxa, 135 molluscan taxa, 78 bryozoan taxa, 29 cnidarian taxa, and 22 echinoderm taxa. Other phyla (n = 9) accounted for the remaining 4 % of the total number of taxa. A table summarising the abundance and biomass values for the most dominant taxa is presented in Table 8. The polychaete worm, *Mediomastus fragilis*, was numerically dominant within the Lundy SAC, with over 2,000 individuals identified from the samples collected, and was found to be the most common taxon present, occurring within 84 % of the stations sampled. The polychaete worm, *Lumbrineris cingulata* aggregate, was also commonly found (occurring within 82 % of stations), as was the bivalve *Abra alba* (77 % of the stations with a mean abundance of six individuals per station). Also of note was the presence of the pea urchin, *Echinocyamus pusillus*, which was present at 71 % of the grab stations.

The geographical distribution of the three univariate metrics of community structure and total biomass is provided in Appendix 5. The six stations to the west of Lundy generally displayed lower abundances and contained fewer species than those to the east (Appendix 5). Five of these western-most stations were dominated by sands (see Section 3.1.2) and may reasonably be expected to differ in their associated infaunal assemblage. While the regions to the north-east and south-east of the surveyed area were generally the most diverse and abundant, species evenness was relatively low at four stations to the east of Lundy, with a maximum of two taxa accounting for 57 – 83 % for the total abundance at any station (Appendix 5). These stations had either high numbers of the annelid *M. fragilis* (LUND06 and LUND29) or had an abundance of the bivalve *Spisula elliptica* (LUND28 and LUND29). Station LUND58 was dominated numerically by the pea urchin *E. pusillus* and the bivalve *Goodallia triangularis*. Total biomass showed a similar distribution to that of species richness and abundance (Appendix 5).

Table 8. Numerical and biomass dominant taxa across the sedimentary habitats of Lundy SAC in 2017 (© Natural England and Cefas 2022).

Taxon	Summed abundance	Occurrence in samples (%)	% contribution to total abundance	Mean abundance per sample	Summed biomass (*g*)
Mediomastus fragilis	2166.0	84.0	13.0	22.0	3.1
Sabellaria spinulosa	1282.0	50.0	8.0	13.0	2.6
Abra alba	575.0	77.0	3.0	6.0	1.5
Echinocyamus pusillus	564.0	71.0	3.0	6.0	1.3
Lumbrineris cingulata agg.	428.0	82.0	3.0	4.0	9.3
*Spisula elliptica**	391.0	2.0	2.0	4.0	293.6
Scalibregma inflatum	388.0	66.0	2.0	4.0	338.4
Mytilidae*	336.0	40.0	2.0	3.0	2.6
Nemertea	336.0	95.0	2.0	3.0	2.2
Bugulidae	78.0	80.0	0.5	0.8	N/A
Crisiidae	71.0	71.0	0.4	0.7	N/A
*Priapulus caudatus**	6.0	6.0	0.0	0.1	11.8
*Aphrodita aculeata**	7.0	5.0	0.0	0.1	5.7
*Upogebia deltaura**	3.0	3.0	0.0	0.0	27.5
*Liocarcinus marmoreus**	26.0	2.0	0.2	0.3	2.8
*Turritellinella tricarinata**	2.0	2.0	0.0	0.0	1.9
*Glycymeris glycymeris**	2.0	2.0	0.0	0.0	629.1
*Dosinia exoleta**	2.0	2.0	0.0	0.0	6.8
*Mya truncata**	1.0	1.0	0.0	0.0	6.5
*Thyone fusus**	1.0	1.0	0.0	0.0	5.2

* indicates the taxa removed from calculation of total biomass

3.1.3.2 Infauna by EUNIS Level 3 Habitat and Annex I Sandbank subfeatures

While a reasonably high number of samples represented ‘A5.1 Sublittoral coarse sediment’ and ‘A5.4 Sublittoral mixed sediments’ (41 and 34 samples respectively), ‘A5.2 Sublittoral sand’ and ‘A5.3 Sublittoral mud’ were represented by fewer samples (15 and 8, respectively). These differences in sample number (and therefore in estimation of within-class variance) must be noted in subsequent interpretations of differences between habitat classes.

A Kruskal-Wallis test was conducted to examine differences in species richness (S) between EUNIS habitat classes. Significant differences were found between the four habitats ($H = 34.5$, $p < 0.001$, $df = 3$). Pairwise comparisons using the Wilcoxon rank sum test confirmed that the infaunal assemblage associated with ‘A5.1 Sublittoral coarse’ sediment samples was significantly ($p < 0.05$) richer in taxa than those of the other BSHs (Figure 13). There was also a significant difference between the abundance values (N) between BSHs ($H = 10.8$, $p < 0.05$, $df = 3$). Pairwise comparisons revealed that this was due to significantly higher abundances in ‘A5.1 Sublittoral coarse sediment’ than in the ‘A5.2 Sublittoral sand’ and ‘A5.3 Sublittoral mud’ classes (Figure 13), while (N) was also high in ‘A5.4 Sublittoral mixed sediments’.

There was no significant difference in Pielou’s species evenness (j’) or total biomass recorded from the four BSHs ($H = 6.1$, $p = 0.1$, $df = 3$; $H = 3.9$, $p = 0.2$, $df = 3$), (Figure 13). A table summarising the descriptive statistics for each habitat class is presented in Appendix 5.

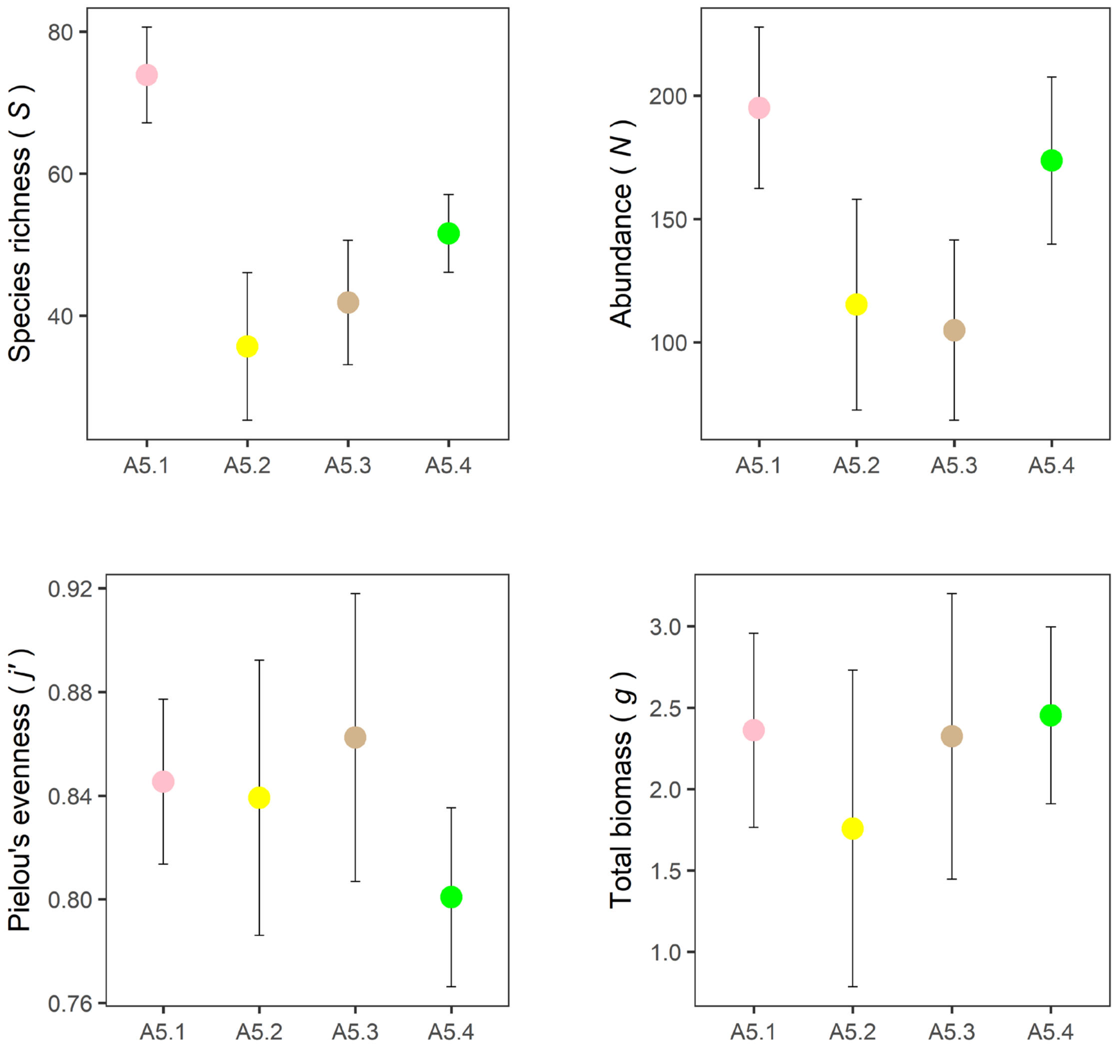

Figure 13. Mean values and 95 % confidence intervals for the univariate metrics of infaunal diversity between EUNIS Level 3 habitat classes ('A5.1 Sublittoral coarse sediment', 'A5.2 Sublittoral sand', 'A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments') at Lundy SAC in 2017 (© Natural England and Cefas 2022).

There were significant differences in the infaunal assemblage structure across EUNIS habitat classes (ANOSIM global R = 0.67, p <0.001). The assemblage structure of 'A5.1 Sublittoral coarse sediment' was significantly different to that of 'A5.2 Sublittoral sand', 'A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments' (Table 9).

Table 9. Results of ANOSIM tests of differences in infaunal assemblage composition between the EUNIS Level 3 habitats sampled at Lundy SAC in 2017 (© Natural England and Cefas 2022). Results in bold are significant at α = 0.05.

EUNIS class comparison	R statistic	Significance (p value)	Average % similarity (SIMPER)
'A5.1 Sublittoral coarse sediment', 'A5.2 Sublittoral sand'	**0.82**	**<0.01**	18.10
'A5.1 Sublittoral coarse sediment', 'A5.3 Sublittoral mud'	**0.91**	**<0.01**	19.30
'A5.1 Sublittoral coarse sediment', 'A5.4 Sublittoral mixed sediment'	**0.76**	**<0.01**	21.80
'A5.2 Sublittoral sand', 'A5.3 Sublittoral mud'	0.09	0.16	23.60
'A5.2 Sublittoral sand', 'A5.4 Sublittoral mixed sediment'	**0.50**	**<0.01**	21.80
'A5.3 Sublittoral mud', 'A5.4 Sublittoral mixed sediment'	0.07	0.25	32.20

These statistical differences were supported by ordination of the samples in multidimensional space whereby stations belonging to a particular EUNIS class (e.g. 'A5.1 Sublittoral coarse sediment') are generally close together on Figure 14. Meanwhile, an overlap of the stations in the plot from 'A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments' is evident which supports the non-significant ANOSIM test for these two habitats (Table 9). The associated stress value of 0.18 infers that the 2d representation gives a potentially useful 2-dimensional picture, although not too much reliance should be placed on the detail of the plot.

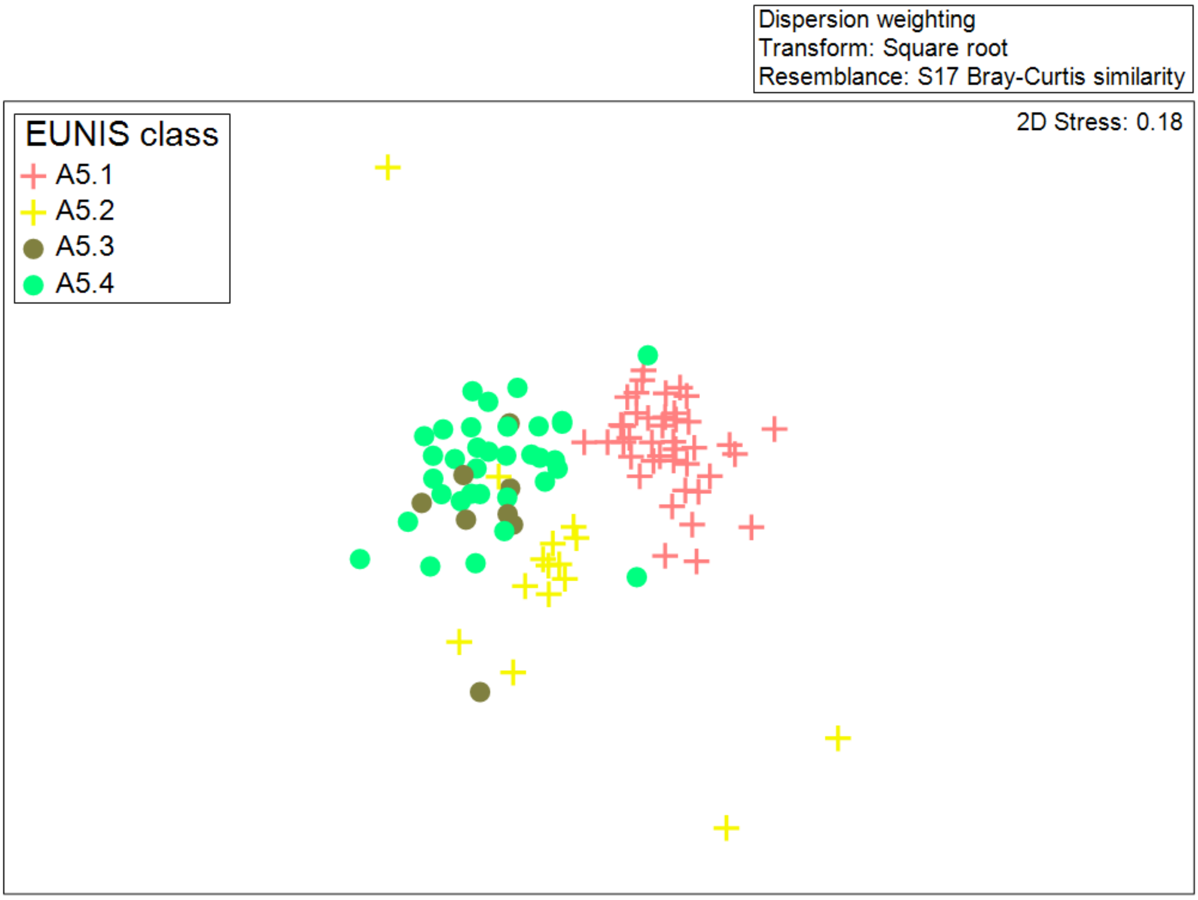

Figure 14. Non-metric Multidimensional Scaling ordination of the Bray-Curtis resemblance matrix from the dispersion weighted, square root transformed 2017 infaunal abundance data (© Natural England and Cefas 2022). The stress value of 0.18 indicates that the plot should only be used to derive broad patterns in the data. Samples representing the Annex I Sandbank feature are indicated using a plus sign (+).

The average similarity among samples within EUNIS classes is generally low, ranging from 22.6 % for 'A5.2 Sublittoral sand' to a maximum value of 36.8 % for 'A5.3 Sublittoral mud'. Generally, similar taxa occur across all EUNIS classes, and any differences appear to be due to differing abundances of taxa common to most (e.g. the polychaete worms *Glycera lapidum* aggregate and *Lumbrineris cingulata* aggregate occurred across all EUNIS classes). There are, however, taxa which are more likely to occur in samples from a particular EUNIS class, and SIMPER analysis revealed that colonial taxa (i.e. animals that live in tightly grouped clusters), such as *Escharella* spp. and *Schizomavella* spp., were more prevalent in 'A5.1 Sublittoral coarse sediment' while the brittle star *Amphiura filiformis* was generally more abundant in 'A5.2 Sublittoral sand' and 'A5.3 Sublittoral mud'. Bamboo worms (Maldanidae) were more abundant in 'A5.4 Sublittoral mixed sediments'.

EUNIS classes 'A5.1 Sublittoral coarse sediment' and 'A5.2 Sublittoral sand' were combined to represent the assemblage associated with the Annex I Sandbank feature. Similarly, the remaining EUNIS classes ('A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments') were combined to represent the benthic assemblage outside Annex I Sandbank feature. The infaunal assemblages were statistically different between these groups (ANOSIM R = 0.46, p < 0.001). The average similarity within the Annex I Sandbank feature group was lower than that of the group representing non-sandbank assemblages (23 % and 33 % respectively). The average dissimilarity between the two groups was 82 % and was generally due to differences in the abundance of taxa common to both groups (Table 10). The pea urchin *E. pusillus* and the gammarid shrimp *Ampelisca spinipes* did have higher average abundances in samples comprising the Annex I Sandbank feature but they were present in samples pertaining to the other group, generally at lower average abundances. The polychaete worm *Sabellaria spinulosa* had a noticeably higher average abundance in the Annex I Sandbank feature assemblages compared to those outside (mean abundance per grab of 21 and 3 individuals respectively). However, the Annex I Sandbank feature group had lower abundances of the polychaete worms *M. fragilis* and *Nephtys kersivalensis* than that of the group comprising samples classified as EUNIS 'A5.3 Sublittoral mud' and 'A5.4 Sublittoral mixed sediments'.

The results of the SIMPER analyses are summarised in Table 10 to compare the average abundance of the ten taxa most responsible for differences between each EUNIS habitat class and between Annex I Sandbank feature habitats and non-sandbank habitats.

Table 10. Results of the SIMPER analysis showing the average dispersion weighted, square root transformed abundance values of the 10 taxa most responsible for the differences between each EUNIS habitat class (© Natural England and Cefas 2022).

Pairwise comparison	Species	A5.1	A5.2	A5.3	A5.4	Av.Diss	Contrib%	Cum %
'A5.1 Sublittoral coarse sediment' & 'A5.2 Sublittoral sand' Average dissimilarity = 81.91	*Schizomavella*	1.0	0.1	N/A	N/A	1.0	1.3	1.3
	Nemertea	1.4	1.0	N/A	N/A	0.9	1.1	2.4
	Ampelisca spinipes	0.8	0.0	N/A	N/A	0.8	1.0	3.4
	Amathia	0.9	0.2	N/A	N/A	0.8	1.0	4.3
	Glycera lapidum agg.	1.0	0.5	N/A	N/A	0.8	1.0	5.3
	Notomastus	0.7	0.0	N/A	N/A	0.8	0.9	6.2
	Porifera	0.8	0.2	N/A	N/A	0.8	0.9	7.1
	Electra pilosa	0.7	0.1	N/A	N/A	0.7	0.9	8.0
	Spiophanes bombyx	0.7	0.4	N/A	N/A	0.7	0.9	8.9
	Escharella	0.7	0.0	N/A	N/A	0.7	0.9	9.8
'A5.3 Sublittoral mud' & 'A5.1 Sublittoral coarse sediment' Average dissimilarity = 80.68	*Magelona alleni*	0.2	N/A	1.1	N/A	1.0	1.3	1.3
	Glycera lapidum agg.	1.0	N/A	0.2	N/A	0.8	1.0	2.3
	Echinocyamus pusillus	0.9	N/A	0.1	N/A	0.8	1.0	3.2
	Nemertea	1.4	N/A	1.0	N/A	0.8	0.9	4.2
	Euclymeninae	0.2	N/A	0.9	N/A	0.7	0.9	5.1
	Ampelisca spinipes	0.8	N/A	0.1	N/A	0.7	0.9	6.0
	Lumbrineris cingulata agg.	0.6	N/A	1.1	N/A	0.7	0.9	6.9
	Spiophanes bombyx	0.7	N/A	0.3	N/A	0.7	0.9	7.7
	Schizomavella	1.0	N/A	0.4	N/A	0.7	0.8	8.6
	Bicellariella ciliata	0.7	N/A	0.0	N/A	0.7	0.8	9.4
'A5.3 Sublittoral mud' & 'A5.2 Sublittoral sand' Average dissimilarity = 76.50	*Magelona alleni*	N/A	0.5	1.1	N/A	1.4	1.8	1.8
	Euclymeninae	N/A	0.1	0.9	N/A	1.3	1.7	3.5
	Nemertea	N/A	1.0	1.0	N/A	1.3	1.6	5.1
	Lumbrineris cingulata agg.	N/A	0.8	1.1	N/A	1.1	1.4	6.5
	Amphiura filiformis	N/A	0.7	0.6	N/A	1.0	1.3	7.9
	Maldanidae	N/A	0.3	0.6	N/A	0.9	1.2	9.1
	Crisiidae	N/A	0.4	0.6	N/A	0.9	1.2	10.3

Pairwise comparison	Species	A5.1	A5.2	A5.3	A5.4	Av.Diss	Contrib%	Cum %
	Atelecyclus rotundatus	N/A	0.3	0.4	N/A	0.9	1.2	11.5
	Spisula	N/A	0.7	0.1	N/A	0.9	1.2	12.7
	Glycera alba	N/A	0.1	0.5	N/A	0.9	1.2	13.9
'A5.4 Sublittoral mixed sediments' & 'A5.1 Sublittoral coarse sediment' Average dissimilarity = 78.18	*Schizomavella*	1.0	N/A	N/A	0.2	0.8	1.0	1.0
	Glycera lapidum agg.	1.0	N/A	N/A	0.3	0.8	1.0	2.0
	Lumbrineris cingulata agg.	0.6	N/A	N/A	1.2	0.7	0.9	2.9
	Mediomastus fragilis	0.3	N/A	N/A	0.9	0.7	0.9	3.8
	Euclymeninae	0.2	N/A	N/A	0.8	0.7	0.8	4.6
	Ampelisca spinipes	0.8	N/A	N/A	0.1	0.7	0.8	5.5
	Echinocyamus pusillus	0.9	N/A	N/A	0.3	0.6	0.8	6.3
	Spiophanes bombyx	0.7	N/A	N/A	0.2	0.6	0.8	7.1
	Magelona alleni	0.2	N/A	N/A	0.7	0.6	0.8	7.8
	Electra pilosa	0.7	N/A	N/A	0.2	0.6	0.8	8.6
'A5.4 Sublittoral mixed sediments' & 'A5.2 Sublittoral sand' Average dissimilarity = 78.22	Euclymeninae	N/A	0.1	N/A	0.8	1.2	1.5	1.5
	Nemertea	N/A	1.0	N/A	1.4	1.1	1.5	2.9
	Lumbrineris cingulata agg.	N/A	0.8	N/A	1.2	1.1	1.4	4.3
	Maldanidae	N/A	0.3	N/A	0.9	1.0	1.3	5.6
	Mediomastus fragilis	N/A	0.6	N/A	0.9	0.9	1.1	6.7
	Amphiura filiformis	N/A	0.7	N/A	0.6	0.9	1.1	7.8
	Caulleriella alata	N/A	0.2	N/A	0.8	0.9	1.1	9.0
	Spisula	N/A	0.7	N/A	0.0	0.9	1.1	10.1
	Magelona alleni	N/A	0.5	N/A	0.7	0.9	1.1	11.2
	Corbula gibba	N/A	0.5	N/A	0.6	0.8	1.0	12.2
'A5.4 Sublittoral mixed sediments' & 'A5.3 Sublittoral mud'	*Magelona alleni*	N/A	N/A	1.1	0.7	0.9	1.4	1.4
	Nemertea	N/A	N/A	1.0	1.4	0.9	1.3	2.7
	Peresiella clymenoides	N/A	N/A	0.6	0.5	0.8	1.2	3.9
	Lysidice unicornis	N/A	N/A	0.5	0.5	0.8	1.2	5.1
	Scalibregmatidae	N/A	N/A	0.4	0.6	0.8	1.2	6.2
	Atelecyclus rotundatus	N/A	N/A	0.4	0.5	0.8	1.1	7.3

Pairwise comparison	Species	A5.1	A5.2	A5.3	A5.4	Av.Diss	Contrib%	Cum %
Average dissimilarity = 67.88	*Mediomastus fragilis*	N/A	N/A	0.6	0.9	0.7	1.1	8.4
	Ampelisca	N/A	N/A	0.5	0.4	0.7	1.1	9.5
	Glycera alba	N/A	N/A	0.5	0.3	0.7	1.1	10.5
	Podarkeopsis capensis	N/A	N/A	0.1	0.5	0.7	1.1	11.6
Annex I Sandbanks feature & Not Annex I Sandbanks feature Average dissimilarity = 82.73	*Mediomastus fragilis*	8.9		39.8		11.5	12.7	12.7
	Sabellaria spinulosa	20.7		3.0		5.0	6.0	18.7
	Abra alba	6.5		5.0		2.7	3.3	22.0
	Echinocyamus pusillus	8.8		1.7		2.6	3.2	25.1
	Scalibregma inflatum	1.7		6.9		2.3	2.8	27.9
	Mytilidae	5.9		0.1		1.9	2.3	30.2
	Lumbrineris cingulata aggregate	2.8		6.5		1.7	2.1	32.3
	Spisula elliptica	2.3		6.3		1.5	1.9	34.2
	Euclymeninae	0.5		4.0		1.3	1.6	35.8
	Nephtys kersivalensis	0.1		3.8		1.2	1.4	37.2

3.1.3.3 Infaunal clusters across the Lundy SAC

A total of 20 statistically different infaunal groups were identified using k-R clustering (R = 0.92). The association between k-R group allocation and EUNIS sediment class is weak, with samples of each infaunal cluster group associated with multiple habitat classes (Table 11, Figure 15). For example, the infaunal group comprising the largest number of samples (group ‘O’) and spanning a wide geographic area (occurring on both the east and western side of Lundy; Figure 15) is observed across all four EUNIS classes. However, samples classified as group ‘O’ have a relatively high average similarity (44 %) and contain numerous colonial taxa and relatively high average abundances of the annelid worm species complex *G. lapidum* aggregate, and the shrimp *A. spinipes*. Meanwhile, the three stations comprising group ‘J’ are each located within different EUNIS habitats. While harbouring assemblages of different taxonomic composition, a number of these k-R cluster groups also vary in their univariate metrics of community structure and total biomass (Figure 16). Group ‘I’, for example, is particularly species rich and contains the greatest infaunal density, while biomass, although being relatively variable, is highest within-group ‘H’. While these faunal groups are statistically different, they should not necessarily be considered as distinct communities.

Table 11. Number of samples (n = 98) of each of the 20 infauna cluster groups (A – T) associated with the four EUNIS Level 3 habitat classes, based on the 2017 sediment PSA from Lundy SAC (© Natural England and Cefas 2022).

EUNIS class	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A5.1		7	1	2	2		2	3	2		4				9	2	1	4	1	1
A5.2	1					1				1		1		2	4	1	1			3
A5.3		1								1	1		2	1	2					
A5.4		2	5	1	1			1		1	9		1		9	1		2	1	

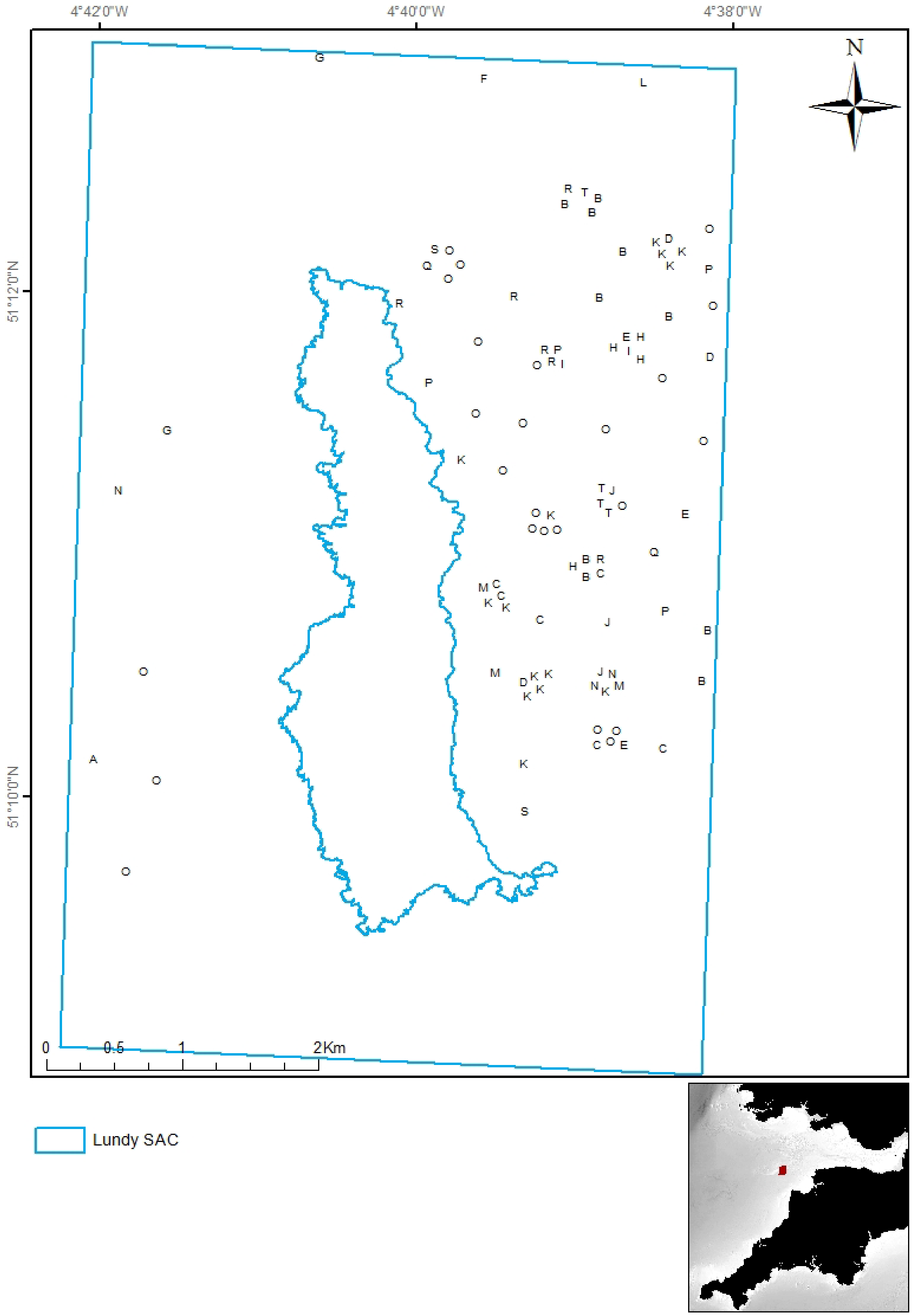

Figure 15. k-R cluster grouped 2017 infaunal data from Lundy SAC, as defined using the ANOSIM R statistic (© Natural England and Cefas 2022). Note, labels of stations with increased replication have been moved to increase clarity and no longer represent the actual location of samples.

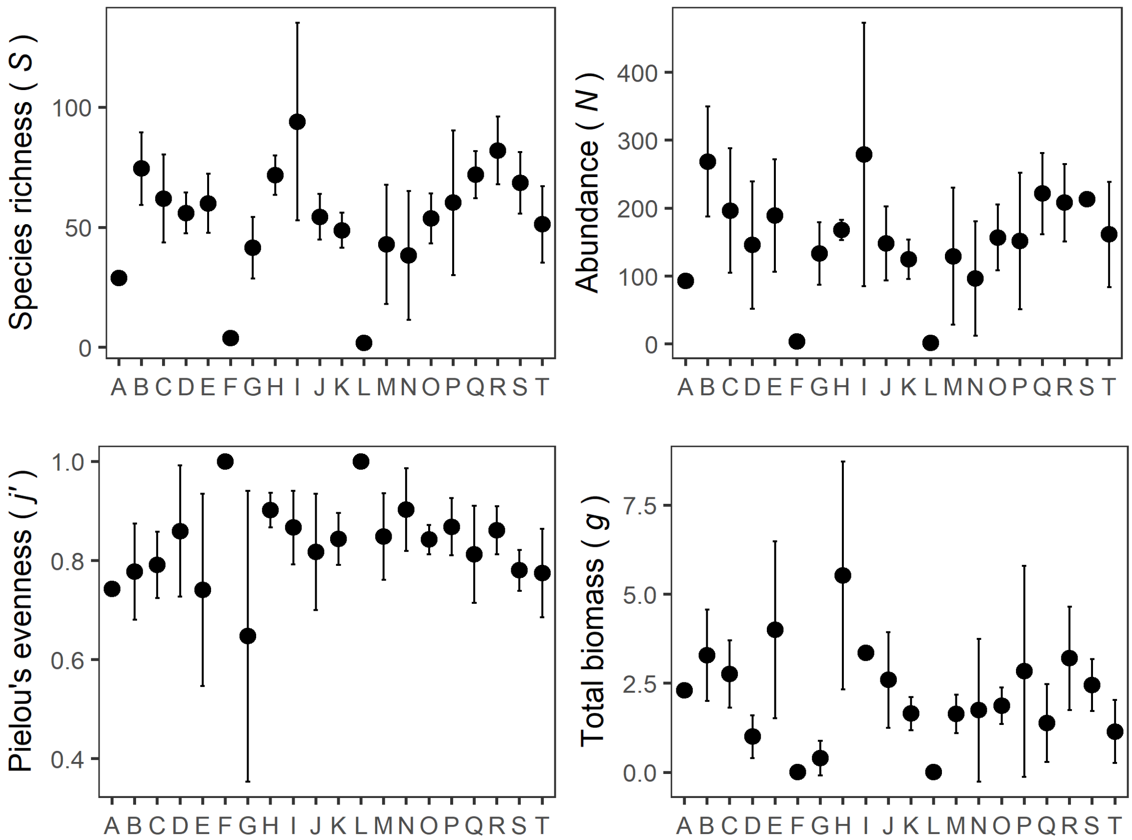

Figure 16. Mean (± 95% CI) univariate metrics of community structure and total wet biomass of the samples belonging to each of the 20 infaunal cluster groups as defined by k-R clustering (© Natural England and Cefas 2022). Data based on samples collected at Lundy SAC, 2017. Clusters A, F and L are outliers represented by a single sample.

3.1.3.4 Infaunal biotopes

A total of eight biotopes were assigned to the mini Hamon grab samples collected during 2017 (Table 12). Most samples (95 %) were assigned to EUNIS Level 5; the two most prevalent classifications being A5.132 (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel), which generally occurs to the south-east of Lundy, and A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment), which was typically found to the north-east of Lundy (Figure 17). *S. spinulosa* density of sediment samples classified as EUNIS Level 5 A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment) ranged from zero, at a single replicate from station LUND30, to > 2000 m^2 at a replicate from station LUND32. While *S. spinulosa* was present in samples classified as A5.132 (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel), A5.451 (Polychaete-rich deep Venus community in offshore mixed sediments) and A5.62 (Sublittoral mussel beds on sediment), it often appeared at lower densities (10 - 150 m^2).

A single example of the EUNIS Level 4 biotope A5.62 (Sublittoral mussel beds on sediment) was identified at station LUND51, to the north of Lundy Island. This sample comprised many (98) individuals of *Mytilus edulis* with a total blotted wet weight of 293.5 g.

Generally, all replicate samples were classified to consistent biotopes at the 12 intensively sampled stations (Figure 17). Replicates of the five northern-most intensively sampled stations were all classified as EUNIS Level 5 A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment). Similarly, replicates of five intensively sampled stations to the east and south-east of Lundy Island were all assigned the EUNIS Level 5 A5.132 (*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel) and all replicates of station LUND31 were classified as EUNIS Level 5 A5.451 (Polychaete-rich deep Venus community in offshore mixed sediments). Replicate samples station LUND55 were classified as either EUNIS Level 5 A5.451 (Polychaete-rich deep Venus community in offshore mixed sediments) or A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment).

Four stations were classified to EUNIS Level 3; A5.1 (Sublittoral coarse sediment) and A5.2 (Sublittoral sand). The A5.2 (Sublittoral sand) stations typically had few taxa (2 to 18) individuals per grab, (mean = 8 ± 7.1) and comprised mostly sand (0.0625 – 2 mm; mean = 91 % ± 15 %).

Table 12. Number of samples assigned to each of the eight EUNIS habitat classifications identified from the mini Hamon grab samples collected during 2017 (© Natural England and Cefas 2022).

Biotope code (Level)	Description	Frequency
A5.1 (L3)	Sublittoral coarse sediment	1
A5.132 (L5)	*Mediomastus fragilis*, *Lumbrineris* spp. and venerid bivalves in circalittoral coarse sand or gravel	37
A5.2 (L3)	Sublittoral sand	3
A5.233 (L5)	*Nephtys cirrosa* and *Bathyporeia* spp. in infralittoral sand	1
A5.251 (L5)	*Echinocyamus pusillus*, *Ophelia borealis* and *Abra prismatica* in circalittoral fine sand	4
A5.451 (L5)	Polychaete-rich deep Venus community in offshore mixed sediments	18
A5.611 (L5)	*Sabellaria spinulosa* on stable circalittoral mixed sediment	33
A5.62 (L4)	Sublittoral mussel beds on sediment	1

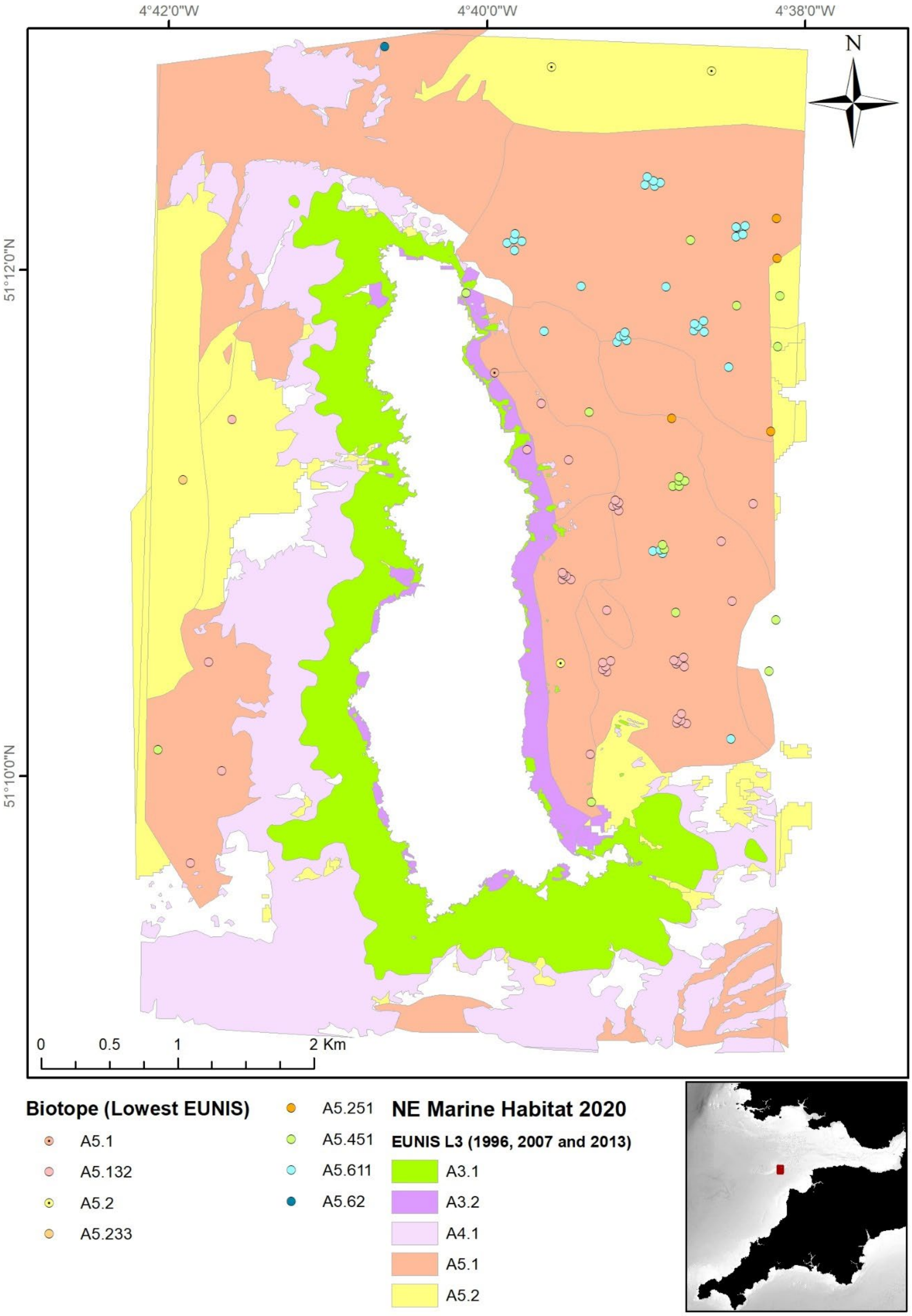

Figure 17. Spatial distribution of the assigned EUNIS habitat classification for each mini Hamon grab sediment sample collected during the 2017 survey (© Natural England and Cefas 2022).

3.1.4 Epibiotic assemblages

3.1.4.1 Epibiotic assemblages across the Lundy SAC

Following truncation and sub-segmentation of still image data, the analysed percentage cover matrix resulted in 66 distinct taxonomic entries, including indeterminate taxa described at the morphological level (morpho-taxa) and consistently identified taxa at the species and genus levels. The taxonomic list included 15 algal entries, 16 porifera entries, nine hydrozoan entries, one cnidarian, two colonial actinians, 15 bryozoan entries, and six colonial ascidian entries. Initial k-means clustering of the benthic morphotaxa and substrate data from the still image samples identified six clusters as the optimal number of partitions (based on the highest SSI criterion value of 0.60).

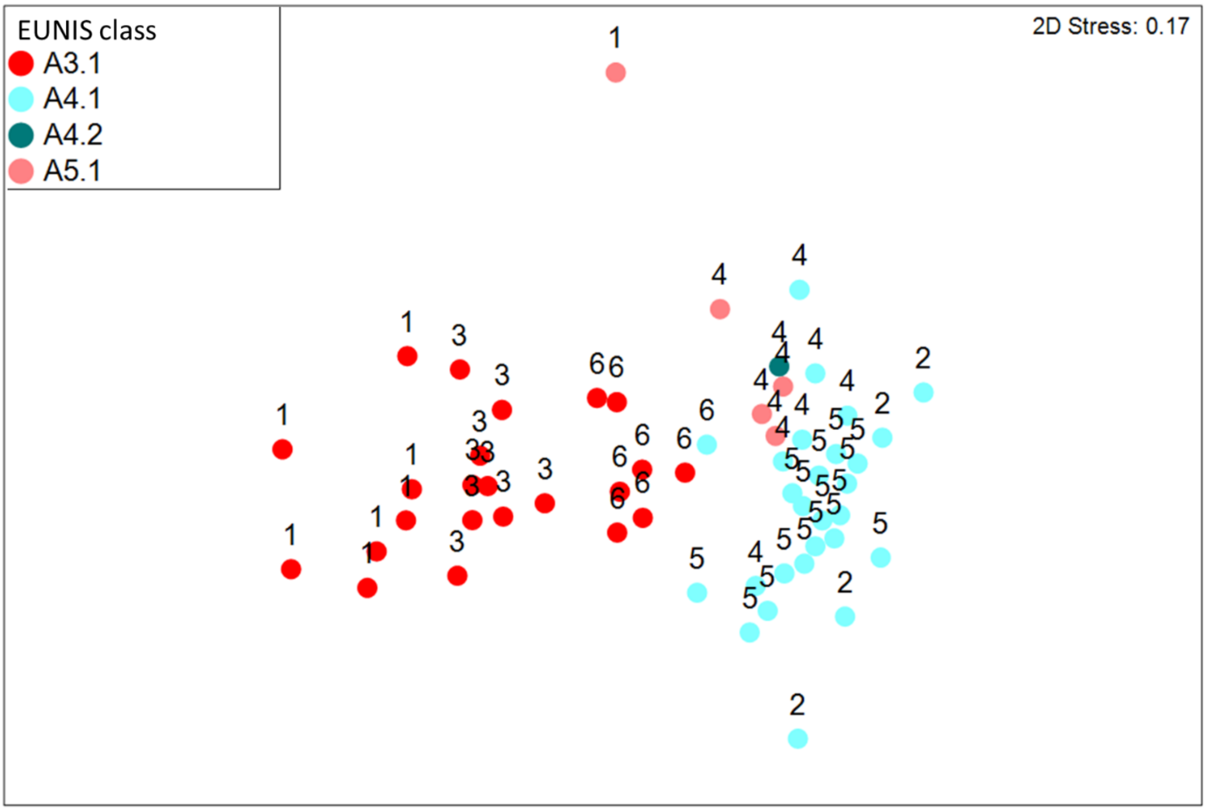

Figure 18. Non-metric multidimensional ordination of the epibiotic percentage cover data based on the still images collected at Lundy SAC, 2017 (© Natural England and Cefas 2022). SIMPROF cluster memberships are overlain, and stations are coloured by the EUNIS Level class they represent. Note that unidentified faunal turf data were removed prior to analysis.

Figure 18 shows a non-metric multidimensional scaling plot of k-R clustered sub-segments with an evident right – left division. The majority of right-side orientated sub-segments were classed as cluster group ‘5’ which is a tight grouping associated with ‘A4.1 Atlantic and Mediterranean high energy circalittoral rock’ (hereafter referred to as ‘A4.1 High energy circalittoral rock’). Cluster group ‘4’ (a component of the right-side grouping) is associated with both ‘A4.1 High energy circalittoral rock’ and ‘A5.1 Sublittoral coarse sediment’. Cluster group ‘4’ has the most heterogenous EUNIS Level 3 association, also including a single segment classed as ‘A4.2 Atlantic and Mediterranean moderate energy circalittoral rock’ (hereafter referred to as ‘A4.2 Moderate energy circalittoral rock’). Cluster group ‘2’ is comprised of four sub-segments, which have been classed as ‘A4.1 High energy circalittoral rock’ and appears more loosely associated with this right-side grouping.

The left-side grouping of cluster groups ‘1’, ‘3’ and ‘6’ (‘A3.1 Infralittoral high energy rock’) was less dense than the right-side division. A single outlier sub-segment is shown within cluster group ‘1’, associated with ‘A5.1 Sublittoral coarse sediment’ and located at the extreme top of the nMDS (Figure 18).

The associated stress value of 0.17 infers that the 2d representation gives a potentially useful picture of the relationships between the stations in multivariate space, though not too much reliance should be placed on the details of the plot.

Pairwise ANOSIM testing with EUNIS Level 3 habitat class as an *a priori* factor (Table 13) shows significant difference in community structure between the sub-segments classed as ‘A4.1 High energy circalittoral rock’ and those classed as ‘A3.1 Infralittoral high energy rock’. Significant differences were also observed between ‘A3.1 Infralittoral high energy rock’ with ‘A5.1 Sublittoral coarse sediment’ and ‘A4.2 Moderate energy circalittoral rock’.

Table 13. Results of ANOSIM tests of differences in epibiotic assemblage composition between the rock and coarse sediment subfeatures sampled at Lundy SAC in 2017 (© Natural England and Cefas 2022). ‘A4.1 Atlantic and Mediterranean high energy circalittoral rock’, which was represented by a single station, was excluded from testing.

EUNIS Level 3 habitat comparison	R statistic	Significance (p value)	Average % similarity (SIMPER)
‘A4.1 Circalittoral high energy rock’, ‘A3.1 Infralittoral high energy rock’	0.772	0.001	21.13
‘A4.1 Circalittoral high energy rock’, ‘A5.1 Sublittoral coarse sediment’	0.302	0.03	36.17
‘A3.1 Infralittoral high energy rock’, ‘A5.1 Sublittoral coarse sediment’	0.742	0.001	18.41
‘A4.1 Circalittoral high energy rock’, ‘A4.2 Circalittoral moderate energy rock’	0.185	0.28	63.48
‘A3.1 Infralittoral high energy rock’, ‘A4.2 Circalittoral moderate energy rock’	0.758	0.042	22.36
‘A5.1 Sublittoral coarse sediment’, ‘A4.2 Circalittoral moderate energy rock’	-0.08	0.66	42.83

There was an evident spatial pattern to the epibiotic assemblages (Figure 19, showing all 359 stills, displayed with their associated cluster group). For example, assemblages ‘1’, ‘3’, and ‘6’ were associated with stations closer to shore, no further than 700 m from Lundy. Cluster ‘4’ was primarily located on the eastern and southern shores, and cluster groups ‘5’ and ‘2’ on the western shore, in notably deeper waters. Sub-segments associated with cluster group ‘4’ are observed in areas with a higher tidal magnitude, aside from GT13_S2 (northeast of the island). The division of EUNIS habitat classes within cluster ‘4’, with one station representing ‘A4.2 Moderate energy circalittoral rock’, therefore matches this discrepancy in association with area of high tidal magnitude.

Figure 19 presents these clusters, and their associated EUNIS Level 3 habitat type, overlying the most current combined habitat map (Natural England, 2020) for the Lundy SAC. There is broad agreement between the EUNIS Level 3 classifications of the cluster groups and the underlying predicted habitats.

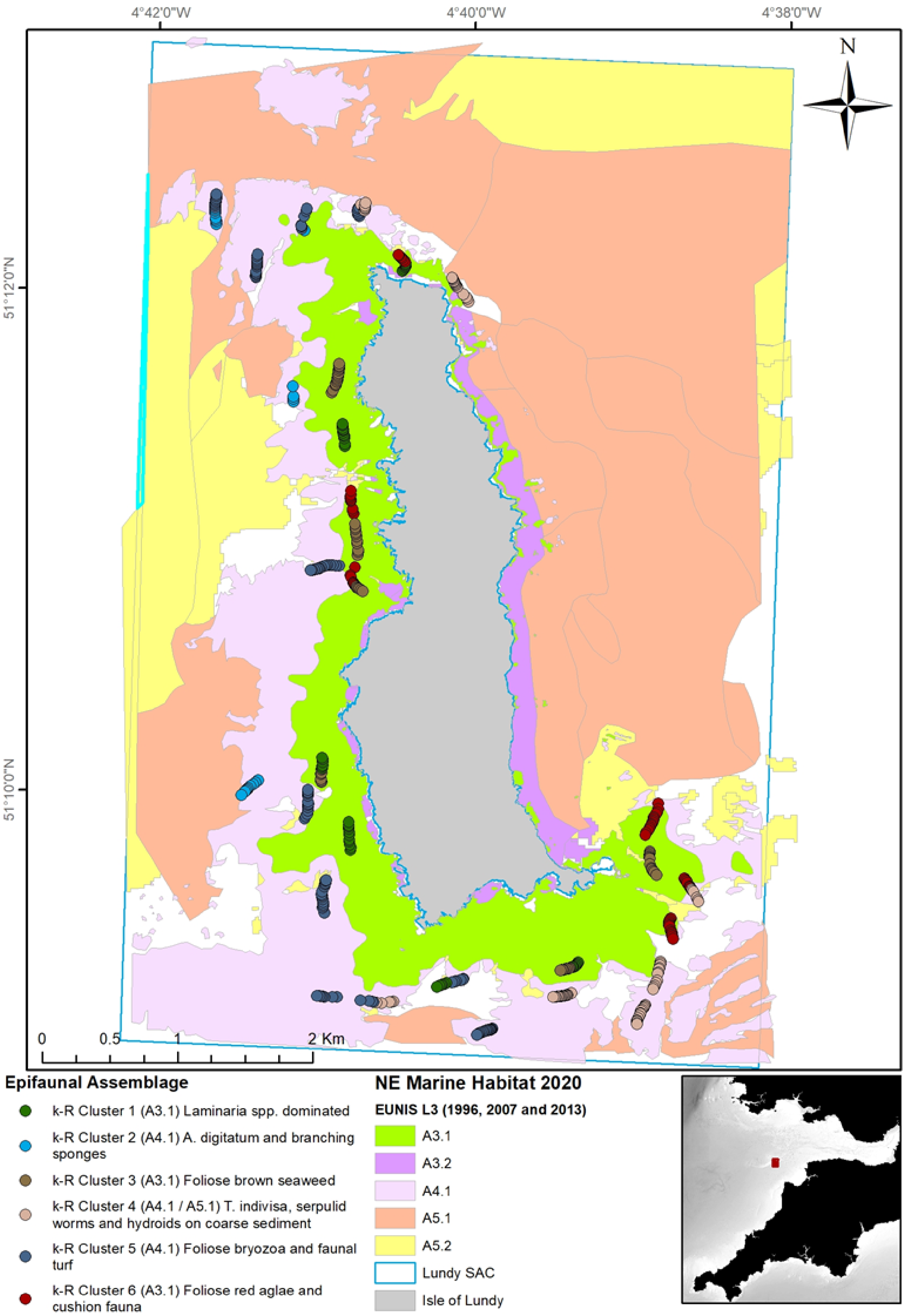

Figure 19. Spatial distribution of the still images used in the epibiotic analysis, with epifaunal assemblage cluster membership assigned to each still used to create the 'sub-segments' used in analysis, overlying the 2020 Open Data Habitat Map (© Natural England and Cefas 2022).

Table 14 presents the results of the Multi-level Pattern analysis on the six primary cluster groups, as defined by k-means clustering. Only those taxa entries that were identified as significant ($p < 0.10$) with an IndVal statistic of > 0.50 are presented within each cluster. The majority of these were significant to $p < 0.01$. Unidentifiable faunal turf and encrusting bryozoa were common across all cluster groups. Within-group similarities (SIMPER) ranged from 32.06 % to 73.64 %.

Table 14. Results from the Multi-level Pattern analysis of epifaunal assemblages (k-means clustering) showing indicator epifaunal taxa by assemblage across the rocky habitats of Lundy SAC in 2017 (© Natural England and Cefas 2022). A and B are components of the IndVal statistic. Taxa are considered characterising if IndVal is > 0.5 and p <0.1.

Cluster	Percent similarity of stations	Main taxa	A	B	IndVal Statistic	p. Value
1	32.06	*Laminaria* spp.	0.80	0.75	0.77	0.00
		Delesseria sanguinea	0.58	0.75	0.66	0.01
2	47.40	*Alcyonium digitatum*	0.64	0.75	0.69	0.02
		Caberea boryi	0.54	0.50	0.52	0.04
		Porifera indet. (repent)	1.00	0.25	0.50	0.07
3	55.72	*Dictyota dichotoma*	0.64	1.00	0.80	0.00
		Dictyopteris polypodioides	0.59	1.00	0.77	0.00
		Red algae indet. (filamentous)	0.55	1.00	0.74	0.00
		Corallinaceae	0.52	1.00	0.72	0.01
		Halidrys siliquosa	0.54	0.78	0.65	0.01
		Brown algae indet. (foliose)	0.39	1.00	0.63	0.01
4	56.67	*Tubularia indivisa* (live)	0.87	0.64	0.74	0.00
		Hydrozoa indet.	0.53	1.00	0.73	0.00
		Serpulidae indet.	0.44	1.00	0.66	0.00
		Cellaria spp.	0.44	1.00	0.66	0.04
		Sertulariidae indet.	0.45	0.64	0.54	0.08
		Bryozoa indet. (encrusting)	0.28	1.00	0.53	0.02
5	73.64	*c.f. Parasmittina trispinosa*	0.46	0.81	0.61	0.03
		Crisularia plumosa	0.41	0.88	0.60	0.05
		Unidentifiable faunal turf	0.36	1.00	0.60	0.00
		Cliona celata (boring)	0.68	0.50	0.59	0.02

Cluster	Percent similarity of stations	Main taxa	A	B	IndVal Statistic	p. Value
6	60.12	*c.f. Electra pilosa*	0.73	0.75	0.74	0.00
		Red algae indet. (foliose)	0.49	1.00	0.70	0.00
		Haliclona viscosa	0.72	0.50	0.60	0.01
		Ascidiacea indet.	0.49	0.63	0.55	0.03
		Polyclinidae (sp. 2)	0.79	0.38	0.54	0.05
		Buguloidea indet.	0.28	1.00	0.53	0.08
		Polyclinidae (sp.1)	1.00	0.25	0.50	0.05

Cluster group '1' had the lowest within-group similarities, whereas clusters '5' and '6' had the highest similarities. *Laminaria* spp. had both high specificity (IndVal component 'A' score of 0.79) and high fidelity (IndVal component 'B' score of 0.75). This indicates that although cluster group '1' has a low within-group similarity, *Laminaria* spp. can be used to characterise this cluster with a high probability of accuracy (IndVal = 0.77, $p < 0.01$). *Delesseria sanguinea* can also be used to effectively classify this assemblage (IndVal = 0.66, $p < 0.01$), however the lower 'IndVal A' component score of 0.58 implies that this species of foliose brown algae is less specific to cluster group '1' than *Laminaria* spp.

Cluster group '2', with a slightly higher SIMPER within-group similarity (47.4 %) can be characterised effectively by the soft coral *Alcyonium digitatum* (IndVal = 0.69, $p < 0.05$) and to a lesser extent by the erect bryozoan *Caberea boryi* (IndVal = 0.52, $p < 0.05$). The low IndVal statistics for these taxa may be associated with much fewer sub-segments comprising the cluster group (i.e. 4 out of 56).

Several brown foliose algal taxa including *Dictyota dichotoma* and *Dictyopteris polypodioides* were particularly characteristic of cluster group '3' (IndVal = 0.80 & 0.77 respectively, $p < 0.01$). This was alongside red algae indet. (filamentous) and Corallinaceae (IndVal = 0.72 & 0.74 respectively, $p < 0.01$). All four of these entries had 'IndVal B' component scores of 1.00, indicating complete fidelity to cluster group '3'.

Cluster group '4' was characterised by live *Tubularia indivisa* (IndVal = 0.74, $p < 0.01$) indeterminable hydrozoa turf (IndVal = 0.73, $p < 0.01$) and serpulid worms (IndVal = 0.66, $p < 0.01$). These latter two entries had low IndVal A component scores (0.53 and 0.44 respectively) and perfect fidelity to the cluster group, meaning that these taxa will always be observed within sub-segments belonging to cluster '4', but they are not uniquely associated with it.

Cluster group '5' is associated with the highest within-group similarity, best characterised by colonies of an encrusting bryozoan which is considered likely to be cf. *Parasmittina trispinosa* (IndVal = 0.61, $p < 0.05$). Although this identification cannot be considered final, as correct identification of turf forming Bryozoa can often require microscopic analysis, the distinct and consistent colouration separate this taxon from other encrusting Bryozoa observed at the site. To a lesser extent (with lower probability) the turf forming bryozoan *Crisularia plumosa* (IndVal = 0.60, p = 0.05) was also considered characteristic. High fidelity of unidentifiable faunal turf is also associated with this cluster group ('IndVal B' component = 1.00), alongside the boring sponge *Cliona celata* (IndVal = 0.58, p < 0.05).

The epiphytic bryozoan cf. *Electra pilosa trispinosa* (IndVal = 0.74, p <0.01) and indeterminable foliose red algae (IndVal = 0.70, p <0.01) had high fidelity to cluster group '6' (IndVal B = 0.75 and 1.00 respectively). Again, formal identification of *E. Pilosa* required microscopic analysis, however the strong association with red algal fronds is indicative of the known life history of this taxon. The encrusting sponge *Haliclona (Rhizoniera) viscosa* is highly specific to this cluster group, but not necessarily always observed (IndVal A = 0.72, IndVal B = 0.50) within the segment comprising the cluster group. Overall, it is considered a moderate indicator of this cluster group '6' (IndVal = 0.60, p <0.01).

Figure 20 shows the nMDS (and k-means cluster groups) and raw abundance of the cup coral *Caryophyllia smithii*. A clear association of this species with 'A4.1 Atlantic and Mediterranean high energy circalittoral rock' can be observed, with a higher percentage cover of *C. smithii* in cluster groups '4', '5' and '6'. Similarly, Figure 21 is overlain with the abundance of the arborescent form of porifera, which shows a close association with cluster '5'.

Example still images representing the visual characteristics of each of the seabed associated with each of the six epibiotic cluster groups are presented in Figure 22.

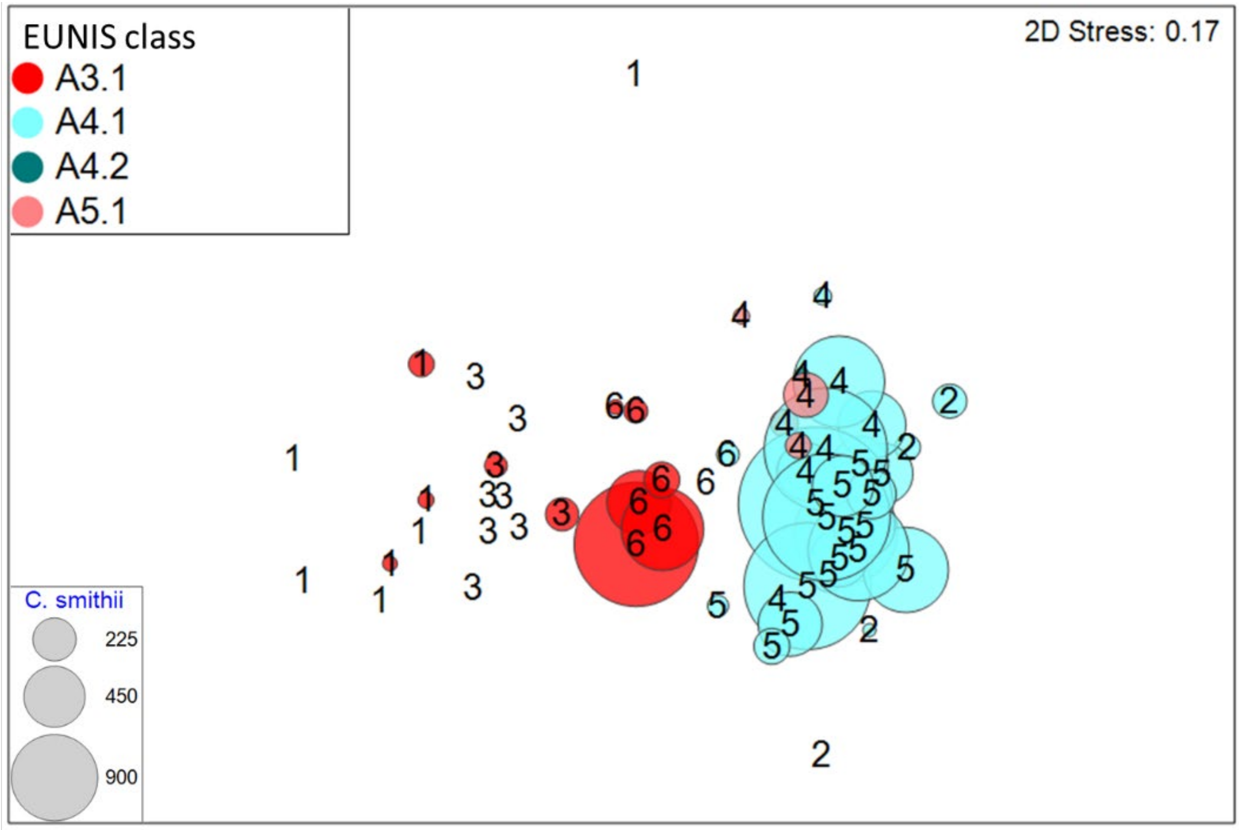

Figure 20. Non-metric multidimensional ordination of the epifaunal percentage cover data based on the still images collected at Lundy SAC, 2017 (© Natural England and Cefas 2022). Abundances of Caryophyllia smithii are overlain. No C. Smithii observed at station classified as A4.2 - hence no bubbles and no visible colouration for this BSH.

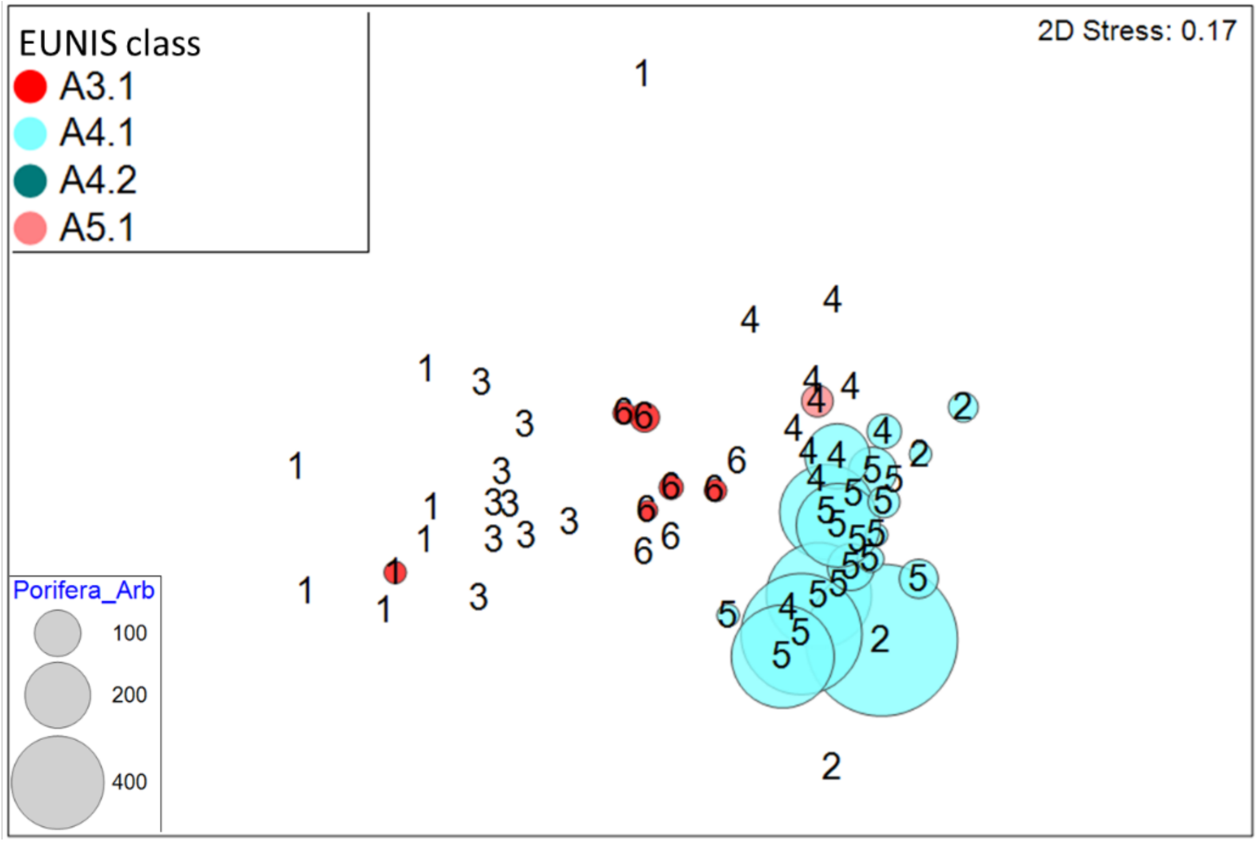

Figure 21. Non-metric multidimensional ordination of the epifaunal percentage cover data based on the still images collected at Lundy SAC, 2017 (© Natural England and Cefas 2022). Abundances of the arborescent form of Porifera are overlain. No Porifera were observed at station classified as A4.2 - hence no bubbles and no visible colouration for this BSH.

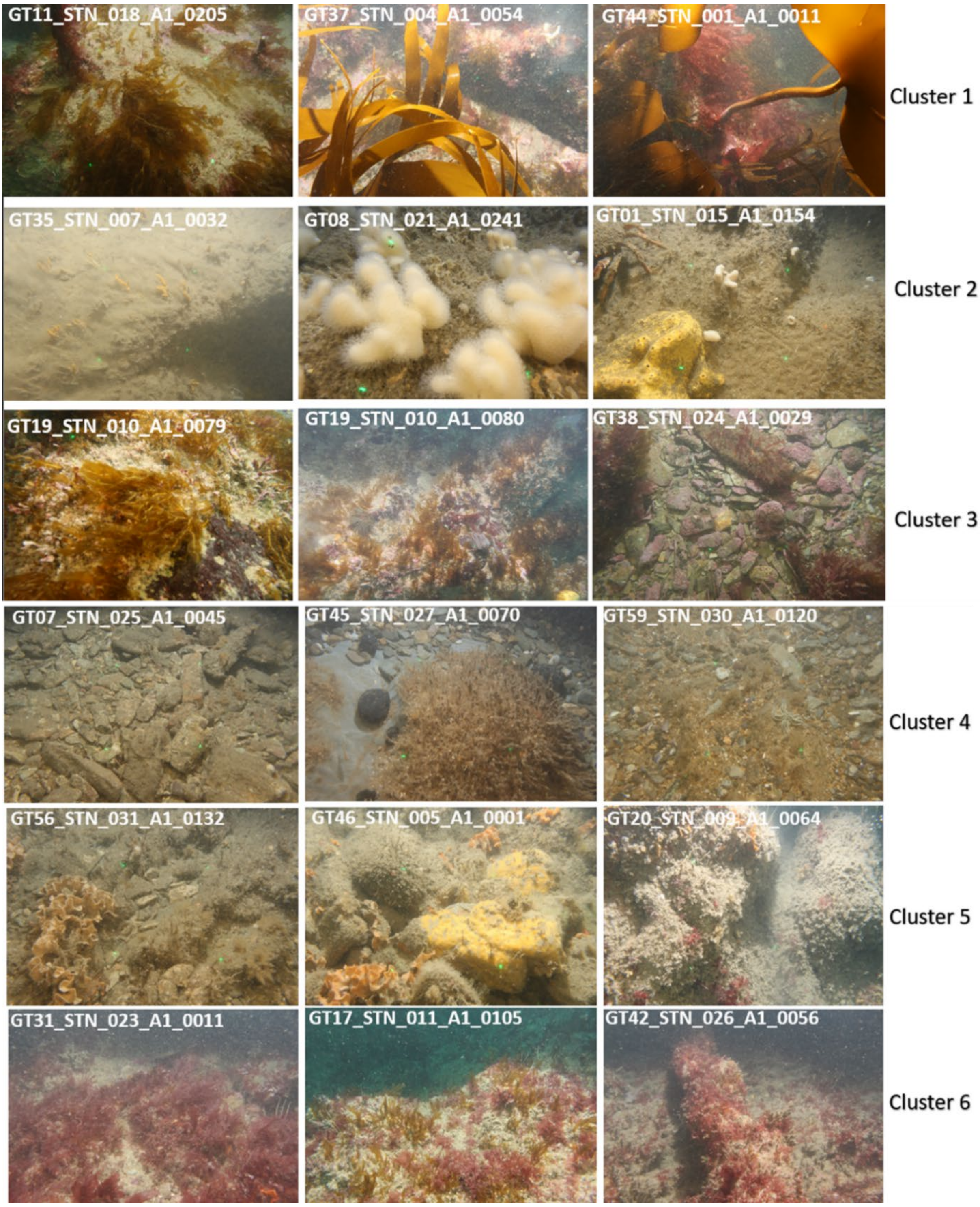

Figure 22. Representative still images for each of the six epibiotic K-means cluster groups (© Cefas and Natural England 2017).

3.1.4.2 Annex I Reef features

Figure 23 presents the distribution of Annex I Reef by sub-segment, showing only those sub-segments which were considered as showing evidence of Annex I Reef features. Three sub-segments of the 40 analysed did not show any evidence of Annex I Reef. Two sub-segments (GT_31_SS1, GT_31_SS2) were considered Annex I 'bedrock and/or stony reef', with a significant veneer of coarse sediment (gravel and sand). The majority of imagery sub-segments with evidence of Annex I 'bedrock' or 'stony' reef are predominantly comprised of bedrock. A higher proportion of boulders was associated with the northern stations, whereas cobbles contributed to larger proportions in the southern, and particularly the south-eastern stations.

The sum of the average hard substrate percentages (bedrock, boulders and cobbles) did not result in 100 % for any sub-segment, owing to the method of taking the mean values from a varying number of stills and the presence of patches of soft substrate in one or more of the component stills. Partial analysis of Annex I Reef subtype (substrate component only) revealed that seven of the 40 segments analysed could be classed as 'bedrock' reef. Four of the sub-segments had average boulder and cobble proportions of greater than 40 %, thus classifying them as the 'stony' reef subtype. Of the remaining sub-segments which had been identified as having evidence of Annex I Reef features, 21 have been classified as 'bedrock and/or stony reef (potential)' and eight as 'not reef'. Figure 24 provides an overview of the distribution of these reef subtypes across the SAC, showing a higher density of bedrock reef stations clustered off the north-western coast of the island, with the 'boulder and/or stony reef (potential)' class associated with circalittoral stations located further offshore.

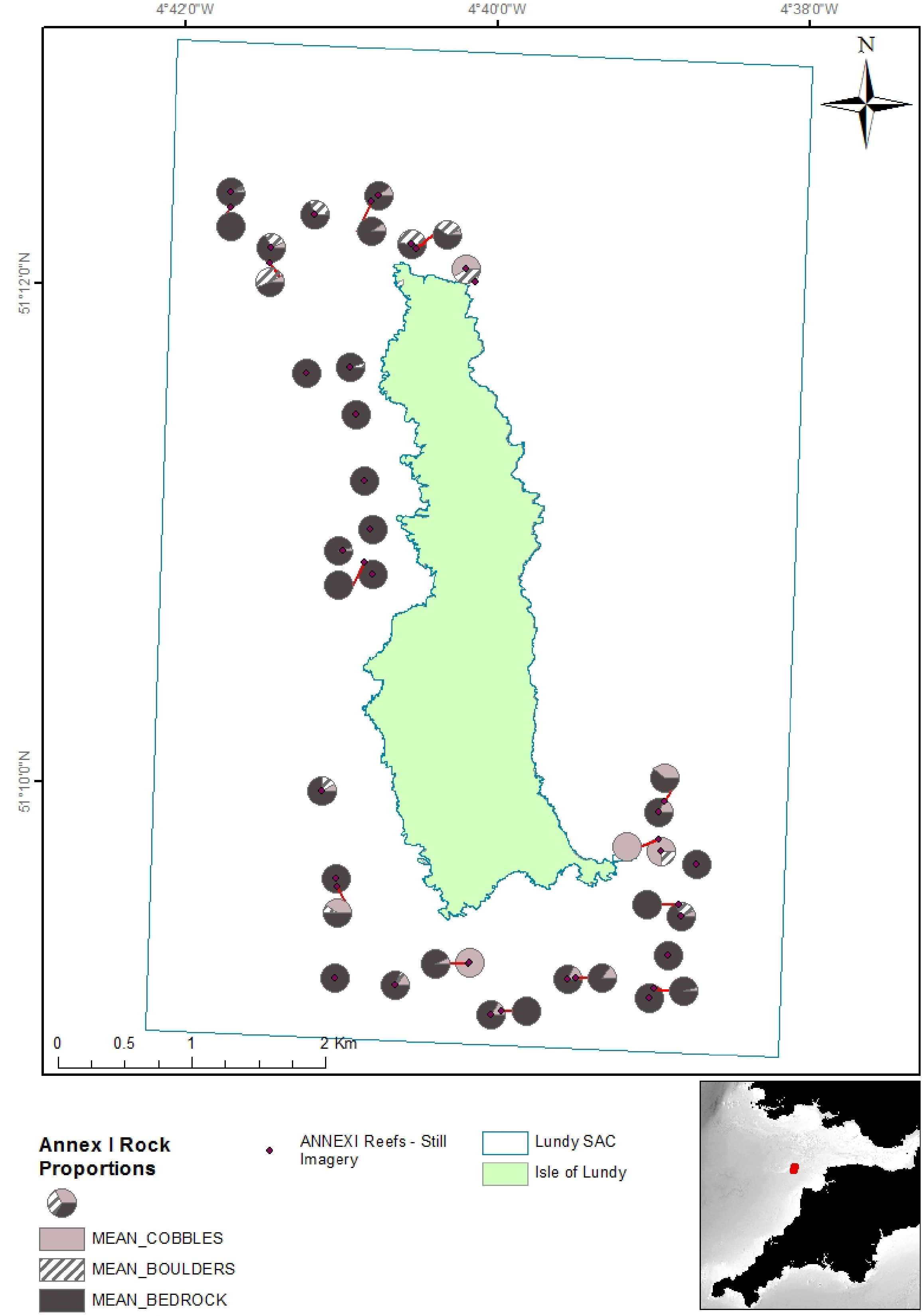

Figure 23. Average proportions of bedrock, boulders and cobbles across still images comprising those station sub-segments which have been classed as containing Annex I Reef (© Natural England and Cefas 2022).

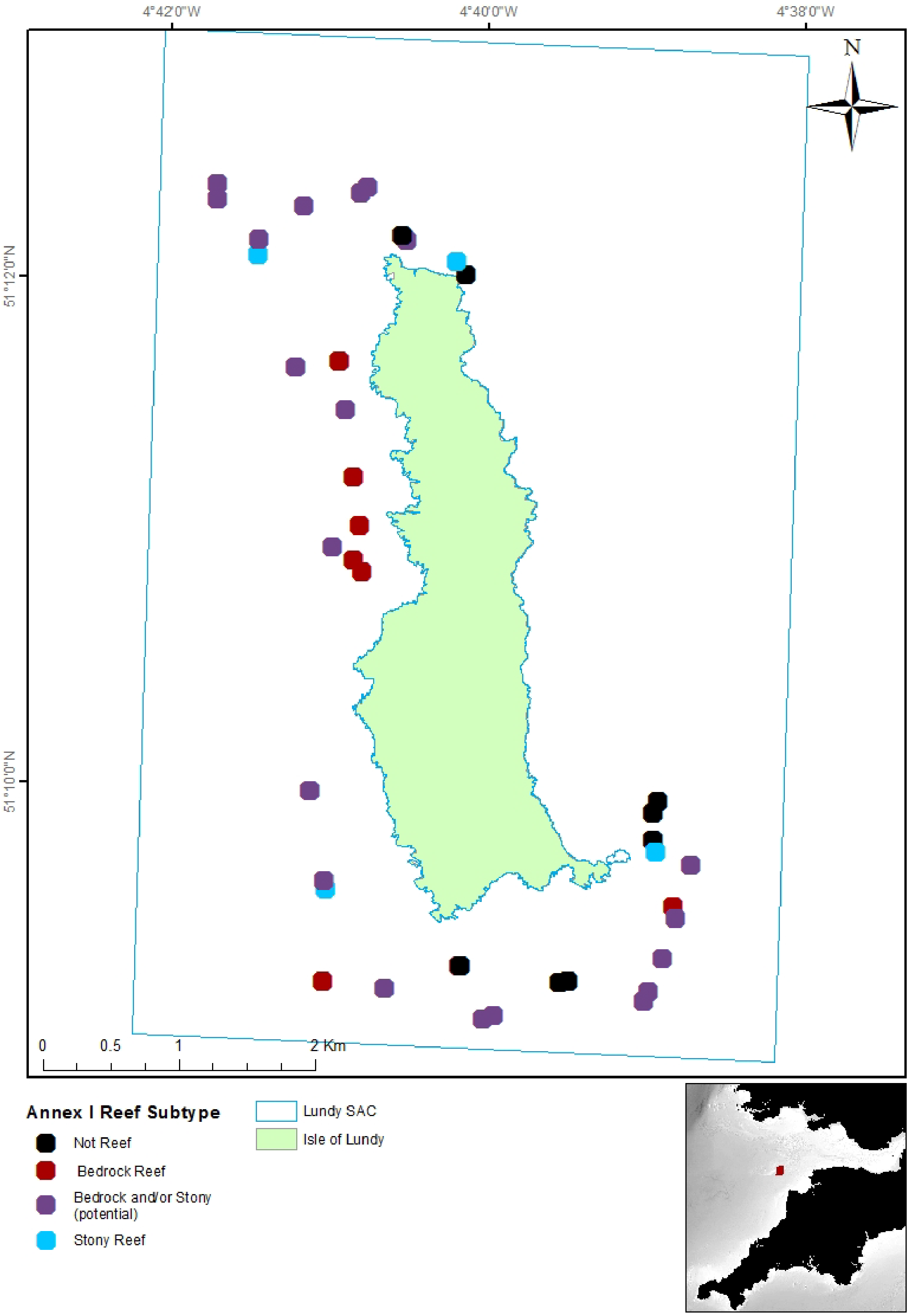

Figure 24. Annex I Reef subtypes assigned to the 56 sub-segments derived from still imagery data from Lundy, 2017 (© Natural England and Cefas 2022).

3.1.4.3 Epibiotic biotopes

Cluster ‘1’ can be very closely matched to the EUNIS Level 4 habitat complex A3.11 (Kelp with cushion fauna and/or foliose red seaweeds), with *Laminaria* spp. defined as an indicator for this cluster. Sub-segments from Cluster ‘3’ were determined to belong to the sub-biotope A3.1161 (Foliose red seaweeds with dense *Dictyota dichotoma* and/or *Dictyopteris membranacea* on exposed lower infralittoral rock). Cluster ‘6’, however, is associated with the biotope A3.116 (Foliose red seaweeds on exposed lower infralittoral rock). Cluster ‘6’ appears to be relatively impoverished in fucoid algal taxa in comparison to cluster ‘3’ which may be due to the proximity of sub-segments defined as cluster ‘6’ to the sedimentary habitat to the east of Lundy. This proximity is likely associated with the coarse sediment veneers observed over flat bedrock at both GT_31 and GT_07, compared with the steep bedrock reefs lacking in coarse sediment observed at and GT_19 (representative of cluster ‘3’).

The assemblages observed at clusters ‘4’, ‘5’, and ‘2’ are primarily associated with habitat complex A4.13 (Mixed faunal turf communities on circalittoral rock), in keeping with the EUNIS Level 3 habitat assigned to the majority of these sub-segments ‘A4.1 High energy circalittoral rock’. The indicator taxa are in keeping with what would be expected within this biotope complex, such as *Alcyonium digitatum*, live *Tubularia indivisa,* turf forming and encrusting bryozoa and sponges (including *Hemimycale columella*) alongside erect bryozoan turf (i.e. *Crisia* spp. and *Crisularia plumosa*) and the jewel anemone *Corynactis viridis*. These taxa are indicative of high energy deeper bedrock and stony reef habitat further offshore of the island. Furthermore, the defined assemblages may be matched with subtidal biotopes previously observed at Lundy.

Cluster group ‘2’ can be characterised effectively by the soft coral *Alcyonium digitatum*, with repent and encrusting porifera, *Flustra foliacea* and, to a lesser extent, *Tubularia indivisa*. As such and owing to the relatively low-density occurrences of *T. indivisa*, the EUNIS Level 5 biotope A4.112 (*Tubularia indivisa* on tide-swept Atlantic circalittoral rock) is considered a close match for this assemblage.

Cluster group ‘4’ was characterised by live *Tubularia indivisa* and other robust hydrozoa including of the family Sertularidae, as such some segments of this cluster group fit well with the EUNIS Level 5 biotope A4.112 (*Tubularia indivisa* on tide-swept Atlantic circalittoral rock). This cluster also appears to exist on a continuum between the biotope A4.112 and the biotope A4.212 (*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock), based upon the relative association between segments assigned to Cluster ‘4’ and prevalence of *C. smithii* (Figure 20), and sagartid anemones.

Cluster group ‘5’ is associated with the highest within-group similarity, with colonies of what are considered likely (given lack of microscopic analysis) to be the encrusting bryozoan *Parasmittina trispinosa* determined to be indicative of the assemblage, and to a lesser extent (with lower probability) the turf forming bryozoan *C. plumosa* and the boring sponge *Cliona celata*. The Devonshire cup coral *C.*

smithii (which was an abundance, as opposed to a percentage cover, taxon), together with the ‘Arborescent porifera’ entry, is considered to be strongly associated with assemblage ‘5’ (Figure 20 and Figure 21 respectively). This cluster appears to comprise a mixture of biotopes, ranging from A4.1312 (Mixed turf of bryozoans and erect sponges with *Dysidea fragilis* and *Actinothoe sphyrodeta* on tide-swept wave-exposed circalittoral rock), to A4.212 (*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock).

C. smithii is considered a particularly important epifaunal characterising taxon, as Lundy is one of the few sites in the UK where all five cup coral species can be observed. Overlay of *C. smithii* into multivariate space (Figure 20) indicates the role of this taxon in the possible gradation of Cluster ‘6’ into Clusters ‘4’ and ‘5’. When viewed in the context of spatial distribution (Figure 19) this gradation can be observed to be toward the predicted extent of EUNIS Level 3 habitat ‘A4.1 High energy circalittoral rock’.

3.2 Objective 2: Conduct a temporal comparison of contaminant levels between 2012 and 2017

3.2.1 Sediment organic carbon and nitrogen

Sediment organic carbon and nitrogen content was measured at five stations to the east of Lundy in 2017. These parameters were not analysed in 2012, therefore no temporal comparisons are possible. Organic carbon content ranged from 0.38 % at LUND08 to 1.32 % at LUND09. LUND08 revealed high proportions of both sand (37.9 %) and gravels (37.6 %) and a moderate proportion of fines (24.6 %). Sediment nitrogen levels were relatively consistent, ranging from 1,060 µg g^{-1} at LUND09 to the north of Lundy to 1,450 µg g^{-1} at LUND04. The geographical distribution of organic carbon and nitrogen is presented in Appendix 6.

3.2.2 Heavy and trace metals

A total of 12 metals were analysed from the five 2017 sediment samples (mercury, aluminium, iron, arsenic, cadmium, chromium, copper, lead, lithium, manganese, nickel, and zinc). The concentrations of these metals are presented in Table 15 and mapped in Appendix 6. Mercury (Hg) and cadmium (Cd) concentrations were generally consistent at all five stations in 2017 and six stations in 2012 indicating no marked changes between survey years. Concentrations of aluminium (Al) and iron (Fe) in 2017 revealed a consistent pattern of distribution, with slightly higher levels recorded at stations LUND13 (the most northerly station) and LUND01 (the most southerly station). In 2012, the highest concentrations were evident at stations NE LUN 01 and NE LUN 02 (the most southerly station, located in Zone 3). Overall concentrations were generally similar between both years, despite the slight changes in the locations of the sampling stations; these differences are likely attributable to discrete variations in the sediment composition within a mixed sediment area and may relate to the proportional contributions of gravel. Concentrations of arsenic were found to be slightly higher in 2017 than in 2012, although within each survey year no obvious pattern of distribution exists. All stations in both surveys were found to exceed the USEPA toxicity reference value for arsenic (TRV; 6 µg g^{-1}), the Canadian Council of Ministers of the Environment (CCME) threshold effect level (TEL) of 7.2 ng g^{-1} and the National Oceanic and Atmospheric Administration (NOAA) Effect Range Low (ERL; 8.2 ng g^{-1}) (Table 15). Concentrations of copper (Cu), lead (Pb), lithium (Li) and manganese were found to be higher in 2012 than in 2017. Variation is also evident for each of these elements between stations within each survey year. These differences are likely related to discrete variations in the sediment composition across the survey area and between surveys. In 2012, copper was found to exceed the CCME TEL (18.7 µg g^{-1}) at all stations, whereas only station LUND04 (towards the south) in 2017 exceeded this level. Lead concentrations exceeded the USEPA TRV (21.0 µg g^{-1}) at all stations in both surveys, with three stations in 2017 and all six in 2012 higher than the CCME TEL (30.2 µg g^{1}) (Table 15).

Table 15. Heavy and Trace Metal Concentrations at Lundy SAC in 2017 (Dry Wt; mg kg^{-1} except aluminium and iron which are presented as mg g^{-1}).

Year	Parameter	Mercury	Aluminium	Iron	Arsenic	Cadmium	Chromium	Copper	Lead	Lithium	Manganese	Nickel	Zinc
Unit		mg/kg	mg/g	mg/g	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
2017	LUND01	0.09	52.40	25.10	13.30	0.07	72.2	16.50	29.00	49.40	493.00	30.50	100.00
	LUND04	0.10	48.10	24.90	15.20	0.10	69.5	20.40	33.10	41.90	509.00	28.90	107.00
	LUND08	0.06	38.60	22.30	15.20	0.06	91.4	13.20	29.60	27.70	454.00	45.30	91.20
	LUND09	0.07	48.20	22.70	12.30	0.09	122.0	13.70	28.80	53.10	440.00	56.10	87.00
	LUND13	0.07	57.20	28.00	14.30	0.09	102.0	16.70	32.80	34.80	474.00	44.40	106.00
	Min	**0.06**	**38.60**	**22.30**	**12.30**	**0.06**	**69.50**	**13.20**	**28.80**	**27.70**	**440.00**	**28.90**	**87.00**
	Max	**0.10**	**57.20**	**28.00**	**15.20**	**0.10**	**122.00**	**20.40**	**33.10**	**53.10**	**509.00**	**56.10**	**107.00**
	Mean	**0.08**	**48.90**	**24.60**	**14.06**	**0.08**	**91.42**	**16.10**	**30.66**	**41.38**	**474.00**	**41.04**	**98.24**
	SD	**0.02**	**6.86**	**2.28**	**1.26**	**0.02**	**21.78**	**2.88**	**2.11**	**10.40**	**28.03**	**11.34**	**8.89**
2012	NE LUN 01	0.08	55.40	28.70	12.80	0.08	107.00	73.50	51.30	66.20	757.00	51.50	132.00
	NE LUN 02	0.07	55.20	29.50	11.50	0.03	97.90	38.60	53.00	63.90	723.00	42.40	121.00
	NE LUN 03	0.07	45.10	23.70	10.10	0.36	85.10	38.70	42.00	54.60	548.00	37.40	102.00

Year	Parameter	Mercury	Aluminium	Iron	Arsenic	Cadmium	Chromium	Copper	Lead	Lithium	Manganese	Nickel	Zinc
	NE LUN 04	0.07	49.30	25.90	10.70	0.03	81.40	28.90	43.90	55.80	576.00	37.50	105.00
	NE LUN 05	0.07	49.00	26.40	10.60	<0.03	122.00	29.30	45.20	58.30	580.00	58.90	109.00
	NE LUN 06	0.07	45.20	24.00	10.30	0.06	81.80	37.20	40.40	53.10	649.00	29.00	102.00
	Min	**0.07**	**45.10**	**23.70**	**10.10**	**0.03**	**81.40**	**28.90**	**40.40**	**53.10**	**548.00**	**29.00**	**102.00**
	Max	**0.08**	**55.40**	**29.50**	**12.80**	**0.36**	**122.00**	**73.50**	**53.00**	**66.20**	**757.00**	**58.90**	**132.00**
	Mean	**0.07**	**49.87**	**26.37**	**11.00**	**0.11**	**95.87**	**41.03**	**45.97**	**58.65**	**638.83**	**42.78**	**111.83**
	SD	**0.00**	**4.57**	**2.37**	**1.00**	**0.14**	**16.33**	**16.52**	**5.09**	**5.29**	**85.80**	**10.80**	**12.16**
USEPA TRV		**-**	**-**	**-**	**6.00**	**1.00**	**8.10**	**28.00**	**21.00**	**-**	**-**	**20.90**	**68.00**
NOAA ERL		**0.15**	**-**	**-**	**8.20**	**1.20**	**81.00**	**34.00**	**46.70**	**-**	**-**	**20.90**	**150.00**
NOAA ERM		**0.71**	**-**	**-**	**70.00**	**9.60**	**370.00**	**270.00**	**218.00**	**-**	**-**	**51.60**	**410.00**
CCME TEL		**0.13**	**-**	**-**	**7.24**	**0.70**	**52.30**	**18.70**	**30.20**	**-**	**-**	**15.90**	**124.00**
CCME PEL		**0.70**	**-**	**-**	**41.60**	**4.20**	**160.00**	**108.00**	**112.00**	**-**	**-**	**42.80**	**271.00**
UK Cefas CAL1		**0.25**	**-**	**-**	**20.00**	**0.40**	**50.00**	**30.00**	**50.00**	**-**	**-**	**30.00**	**130.00**
UK Cefas CAL2		**1.50**	**-**	**-**	**70.00**	**4.00**	**370.00**	**300.00**	**400.00**	**-**	**-**	**150.00**	**600.00**

3.2.3 Polycyclic Aromatic Hydrocarbons (PAHs)

The 2017 and 2012 results for the 10 PAHs measured are given below in Table 16, and the distribution of two of the more volatile PAHs, Naphthalene and Phenanthrene, in 2017 are illustrated in Appendix 6. Table 16 also includes relevant reference concentrations of PAHs from the CCME from 2001 and 2002, NOAA (1996), OSPAR (2004) and the North Sea SEA2 assessment reported in 2001 (Sheahan *et al.*, 2001). For most PAHs, concentrations were generally within the same range in both 2012 and 2017, and, given the inshore location of Lundy SAC, there is a possibility of frequent inputs of PAHs through terrestrial sources and atmospheric exchange. Spatially there was some variation in the data, with station LUND13 in 2017 (located in the north of Zone 3), revealing the highest concentrations of all PAHs measured. PAH levels at LUND09 in the same year were also relatively high compared with the remaining stations. Given the limited number of sampling stations for sediment contaminants, it cannot be determined whether there is a specific trend with higher PAHs reported to the northeast of Lundy, or whether this is a factor of sediment composition and occurs throughout the area or region.

For benzo(a)anthracene, two samples in 2017 and three in 2012 were above the Sediment Quality Guidelines (SQG) value defined by CCME of 74.8 ng g^{-1} (CCME, 2002) (Table 16). In addition, two of these stations also exceeded the reference for North Sea cuttings piles (100.0 ng g^{-1}; Sheahan *et al.*, 2001): LUND13 in 2017 and NE LUN 04 in 2012.

Benzo(a)pyrene was also found at levels above those described for North Sea cuttings piles (7 ng g^{-1}; Sheahan *et al.*, 2001) at all stations in both 2012 and 2017. In 2017 the highest concentration was found at LUND13 and in 2012 at NE LUN 04 (concurrent with benzo(a)anthracene). Concentrations ranged from 48.3 ng g^{-1} to 116.0 ng g^{-1} in 2017 (mean 71.1 ng g^{-1}), and 43.2 ng g^{-1} to 118.0 ng g^{-1} in 2012 (mean 71.8 ng g^{-1}) demonstrating the overall consistency between survey years.

Benzo(ghi)perylene and indeno(1,2,3-c,d)pyrene were generally consistent between survey years with 2012 means of 52.3 ng g^{-1} and 52.5 ng g^{-1} respectively, and 2017 means of 59.0 ng/g and 49.6 ng g^{-1}. In 2017, results were consistent at stations LUND01 to 03, with elevated concentrations evident at stations LUND13 and 09 in the north of Zone 3.

Chrysene + triphenylene and fluoranthene revealed consistent distribution patterns in the 2017 survey, with the highest concentrations identified at stations LUND03 and 09, and the lowest concentrations at station LUND08. The overall mean concentrations for both PAH groups were higher in 2017 (chrysene + triphenylene: 107.5 ng g^{-1}, fluoranthene: 146.9 ng g^{-1}) than in 2012 (85.2 ng g^{-1} and 108.3 ng g^{-1}) although stations within both surveys exceeded the CCME SQG of 108.0 ng g^{-1} (chrysene + triphenylene) and 113.0 ng g^{-1} (fluoranthene).

Concentrations of pyrene were variable between stations and survey years, with a higher overall mean calculated in 2017 (113.2 ng g^{-1}) as opposed to a mean of 80.9 ng g^{-1} in 2012. Consistent with all other PAH results in 2017, the highest concentrations of pyrene were recorded at stations LUND13 and LUND09. LUND13 in 2017 was the only station found to exceed the CCME SQG and TEL for pyrene of 153.0 ng g^{-1}.

Anthracene concentrations were low when compared with other PAHs in both 2017 and 2012, although in 2017 followed the same trend as other PAHs, with highest concentrations evident at stations LUND13 and LUND09.

All stations in 2017 and five in 2012 revealed naphthalene concentrations above the CCME SQG and TEL of 34.6 ng g^{-1}. The mean concentration in both survey years was consistent however, with 55.3 ng g^{-1} in 2017 and 55.6 ng g^{-1} in 2012. Phenanthrene levels were above the CCME SQG and TEL of 86.7 ng g^{-1} at two stations in 2017 and three stations in 2012. Station NE LUN 05 (2012) was re-sampled in 2017 as LUND13, and the concentration of this PAH was found to be more than double the 2012 result in 2017 (215.0 ng g^{-1}). This difference is potentially attributable to the patchy nature of the substrate, with pockets of sediment containing higher proportions of fines which are more likely to retain PAHs than sandy substrates due to the increased surface area available for adsorption of contaminants. In support of this, the PSA sample in 2017 comprised 19.6 % fines, whereas the equivalent station in 2012 contained just 1.1 % fines. Given the volatility of these two PAHs, it likely that these inputs are petrogenic in nature, and may be the result of a chronic source.

Table 16. Polycyclic Aromatic Hydrocarbon (PAH) Concentrations at Lundy SAC in 2017 (Dry Wt, ng g^{-1}) (© Natural England and Cefas 2022).

Year	Parameter	Anthracene	Benzo(a)-anthracene	Benzo(a)-pyrene	Benzo(ghi)-perylene	Chrysene + Triphenylene	Fluoranthene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Pyrene
2017	LUND01	19.7	58.3	50.9*	40.3	82.6	101.0	35.8	43.4*	80.7	77.5
	LUND04	18.6	58.6	59.9*	53.5	84.6	106.0	43.7	59.1*	83.4	88.5
	LUND08	13.8	49.0	48.3*	40.0	70.5	98.3	34.4	35.6*	73.3	76.8
	LUND09	25.1	88.0*	80.3*	67.0	124.0*	149.0*	56.0	68.2*	120.0*	118.0
	LUND13	49.4*	131.0*	116.0*	94.4	176.0*	280.0*	78.0	70.1*	215.0*	205.0*
	Min	13.8	49.0	48.3	40.0	70.5	98.3	34.4	35.6	73.3	76.8
	Max	49.4	131.0	116.0	94.4	176.0	280.0	78.0	70.1	215.0	205.0
	Mean	25.3	77.0	71.1	59.0	107.5	146.9	49.6	55.3	114.5	113.2
	SD	14.0	33.6	28.1	22.7	43.2	77.2	18.1	15.2	59.0	54.0
2012	NE LUN 01	16.8	51.0	50.5*	39.9	66.4	88.0	40.3	43.7*	81.6	65.7
	NE LUN 02	21.1	77.1*	92.2*	61.6	93.2	108.0*	62.2	56.8*	95.5*	86.1
	NE LUN 03	11.4	41.5	43.2*	32.3	49.7	63.4	32.5	30.8	46.1	51.1

Year	Parameter	Anthracene	Benzo(a)-anthracene	Benzo(a)-pyrene	Benzo(ghi)-perylene	Chrysene + Triphenylene	Fluoranthene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Pyrene
	NE LUN 04	38.9	128.0*	118.0*	86.1	150.0*	193.0*	85.9	97.9*	128.0*	133.0
	NE LUN 05	23.2	81.3*	82.7*	58.4	101.0	130.0*	58.6	62.2*	89.0*	96.1
	NE LUN 06	12.2	40.8	44.1*	35.4	51.0	67.4	35.4	42.3*	55.1	53.2
	Min	11.4	40.8	43.2	32.3	49.7	63.4	32.5	30.8	46.1	51.1
	Max	38.9	128.0	118.0	86.1	150.0	193.0	85.9	97.9	128.0	133.0
	Mean	20.6	70.0	71.8	52.3	85.2	108.3	52.5	55.6	82.6	80.9
	SD	10.1	33.4	30.7	20.5	38.2	48.5	20.4	23.5	29.5	31.2
CCME ISQG		49.9	74.8	88.8	N/A	108.0	113.0	N/A	34.6	86.7	153.0
CCME TEL		46.9	N/A	88.8	N/A	N/A	113.0	N/A	34.6	86.7	153.0
CCME PEL		245.0	693.0	763.0	N/A	846.0	1,494.0	N/A	391.0	544.0	1,398.0
NOAA ERL		85.3	N/A	N/A	N/A	N/A	N/A	N/A	160.0	240.0	N/A
NOAA ERM		1,100.0	N/A	N/A	N/A	N/A	N/A	N/A	2,100.0	1,500.0	N/A

Year Parameter	Anthracene	Benzo(a)-anthracene	Benzo(a)-pyrene	Benzo(ghi)-perylene	Chrysene + Triphenylene	Fluoranthene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Pyrene
OSPAR EAC	50.0-500.0	N/A	100.0-1,000.0	N/A	N/A	500.0-5,000.0	N/A	50.0-500.0	100.0-1,000.0	50.0-500.0
SEA2 Ref	12,000.0	100.0	7.0	N/A	N/A	100.0	N/A	75,000.0	3,000.0	500.0

* Denotes those which are close to or above the listed effect levels and quality guidelines. SEA2 References for PAHs refer to those within North Sea cutting piles (i.e, surrounding oil and gas installations, Sheahan *et al.*, 2001).

3.2.4 Hexachlorobutadiene and Hexachlorobenzene

Hexachlorobenzene and Hexachlorobutadiene (HCBD) were found to be below the limits of detection (LOD; 0.1 ng g^{-1}) at all five stations sampled. No samples were analysed for these parameters in 2012, therefore no temporal comparison is possible at this time.

3.2.5 Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) of seven congeners (028, 052, 101, 118, 138, 153, 180) were analysed. The results are presented in Table 17 and illustrated in Appendix 6. In 2012, concentrations of all PCB congeners, except congener 138, 153 and 182 at LUN 01 and congener 128 at LUN 04, were below the LOD (0.1 ng g^{-1}; Table 17). PCB concentrations in 2017 were low throughout, although congener 028 at station LUND13 (1.2 ng g^{-1}) falls within the OSPAR Environmental Assessment Criteria (EAC) range of 1.0-10.0 ng g^{-1} (Bignert *et al.*, 2004). Background levels within the western North Sea have historically been found to be <2.0 ng g^{-1}, with open sea concentrations generally <1.0 ng g^{-1} (Sheahan *et al.*, 2001). Concentrations of PCBs have fluctuated slightly between the two survey years; however, levels have remained consistently low. All concentrations in both survey years are below the western North Sea reference of 2.0 ng g^{-1} (Sheahan *et al.*, 2001).

Table 17. Polychlorinated Biphenyl (PCBs) concentrations at Lundy SAC in 2017 and 2012 (Dry Wt, ng g^{-1}) (© Natural England and Cefas 2022).

Year	Station	PCB Congener (ng/g)						
		PCB-028	PCB-052	PCB-101	PCB-118	PCB-138	PCB-153	PCB-180
2017	LUND01	0.61	0.14	<0.10	<0.10	<0.10	<0.10	0.13
	LUND04	0.83	0.24	<0.10	0.18	<0.1	<0.10	0.28
	LUND08	0.70	0.13	<0.10	<0.10	<0.10	<0.10	0.15
	LUND09	0.81	0.17	<0.10	<0.10	<0.10	<0.10	0.29
	LUND13	1.15*	0.22	<0.10	<0.10	<0.10	<0.10	0.32
	Min	0.61	0.13	0.00	0.18	0.00	0.00	0.13
	Max	1.15	0.24	0.00	0.18	0.00	0.00	0.32
	Mean	0.82	0.18	N/A	0.18	N/A	N/A	0.23
	SD	0.20	0.05	N/A	N/A	N/A	N/A	0.09
2012	NE LUN 01	0.60	0.24	0.52	0.56	1.00*	1.28*	1.68*
	NE LUN 02	0.80	0.24	0.32	0.44	0.52	0.60	0.36
	NE LUN 03	0.40	<0.10	0.12	0.20	0.28	0.32	0.24
	NE LUN 04	1.32*	0.40	0.52	0.68	0.84	0.92	0.64

Year	Station	PCB Congener (ng/g)						
		PCB-028	PCB-052	PCB-101	PCB-118	PCB-138	PCB-153	PCB-180
	NE LUN 05	0.80	0.28	0.32	0.40	0.44	0.56	0.28
	NE LUN 06	0.72	0.20	0.24	0.36	0.48	0.52	0.32
	Min	0.40	0.20	0.12	0.20	0.28	0.32	0.24
	Max	1.32	0.40	0.52	0.68	1	1.28	1.68
	Mean	0.77	0.27	0.34	0.44	0.59	0.70	0.59
	SD	0.31	0.08	0.16	0.17	0.27	0.34	0.55
CCME TEL		21.50	21.50	21.50	21.50	21.50	21.50	21.50
CCME PEL		189.00	189.00	189.00	189.00	189.00	189.00	189.00
OSPAR EAC		1.00-10.00	1.00-10.00	1.00-10.00	1.00-10.00	1.00-10.00	1.00-10.00	1.00-10.00
NOAA ERL		22.70	22.70	22.70	22.70	22.70	22.70	22.70
NOAA ERM		180.00	180.00	180.00	180.00	180.00	180.00	180.00
SEA2 Ref		<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00

*Denotes those which are above the listed effect levels and quality guidelines. SEA2 References for PCBs refer to generic PCB concentrations in offshore sediments within the North Sea as reported by Sheahan *et al.* (2001).

3.2.6 Polybrominated Diphenyl Ethers

Six polybrominated diphenyl ethers (PBDEs) were analysed; results for both surveys are presented in Table 18 and mapped in Appendix 6.

In 2017, PBDE 28 was found to be below the LOD at all stations and PBDE 154 was below the LOD at station LUND09. In 2012, all congeners except PBDE 47 were found to be below the LOD of 0.10 ng g^{-1}, although it should be noted that the LOD was higher during this survey and is therefore less likely to identify trace levels (Table 18).

In the 2017 samples concentrations for all congeners (where recorded above the LOD) were highest at LUND08 and LUND04, with PBDE 99 recording the highest overall concentrations at these stations (0.26 ng g^{-1} and 0.17 ng g^{-1}, respectively). Mean concentrations of PBDEs across this OSPAR region are generally found to be low and below 1.00 ng g^{-1} in marine sediments (OSPAR, 2017), therefore, the results for Lundy are generally consistent with OSPAR values.

Results for PBDE 47 were slightly higher in 2012 than in 2017, however all results are still well below 1.00 ng g^{-1} and are therefore considered broadly consistent with the UK assessment areas (OSPAR, 2017).

The LOD in 2012 was 0.1 ng g-1 for all congeners whereas in 2017 the LOD was 0.02 ng g-1 for congeners PBDE 153, 154, 100 and 28, 0.05 ng g-1 for PBDE 99 and 0.07 ng g-1 for PBDE 47.

3.2.7 Organotins

Results from the 2012 and 2017 surveys for Tributyltin (TBT) reveal that all samples in 2012 were below the LOD (3.00 ng g^{-1}), and three samples in 2017 were also below the LOD (despite a revised LOD to 1.00 ng g^{-1}; Table 19). All samples in 2012 were below the LOD (3.00 ng g^{-1}), and three samples in 2017 were also below the LOD, despite an improved LOD of 1.00 ng g^{-1}. A concentration of 2.59 ng g^{-1} was recorded in 2017 at station LUND01 in the south of Zone 3, and 1.80 ng g^{-1} at station LUND09 slightly further north. Both stations fell below the OSPAR EAC range of 5.00-50.00 ng g^{-1} and can be considered relatively low.

Table 18. Polybrominated Diphenyl Ether (PBDE) Concentrations at Lundy SAC in 2017 and 2012 (Dry Wt, ng g^{-1}) (© Natural England and Cefas 2022).

Year	Station	Polybrominated Diphenyl Ether (ng g^{-1})					
		PBDE 153	PBDE 154	PBDE 99	PBDE 100	PBDE 47	PBDE 28
LOD		0.02	0.02	0.05	0.02	0.07	0.02
2017	LUND01	0.02	0.02	0.08	0.03	0.07	<0.02
	LUND04	0.04	0.03	0.17	0.04	0.13	<0.02
	LUND08	0.15	0.08	0.26	0.05	0.09	<0.02
	LUND09	0.03	<0.02	0.07	0.02	0.08	<0.02
	LUND13	0.03	0.02	0.07	0.02	0.08	<0.02
	Min	**0.02**	**0.02**	**0.07**	**0.02**	**0.07**	**N/A**
	Max	**0.15**	**0.08**	**0.26**	**0.05**	**0.13**	**N/A**
	Mean	**0.06**	**0.04**	**0.13**	**0.03**	**0.09**	**N/A**
	SD	**0.06**	**0.03**	**0.09**	**0.01**	**0.02**	**N/A**
2012	NE LUN 01	<0.10	<0.10	<0.10	<0.10	0.12	<0.10
	NE LUN 02	<0.10	<0.10	<0.10	<0.10	0.11	<0.10
	NE LUN 03	<0.10	<0.10	<0.10	<0.10	<0.10	<0.10
	NE LUN 04	<0.10	<0.10	<0.10	<0.10	0.16	<0.10
	NE LUN 05	<0.10	<0.10	<0.10	<0.10	0.12	<0.10
	NE LUN 06	<0.10	<0.10	<0.10	<0.10	0.11	<0.10
	Min	**N/A**	**N/A**	**N/A**	**N/A**	**0.11**	**N/A**
	Max	**N/A**	**N/A**	**N/A**	**N/A**	**0.16**	**N/A**
	Mean	**N/A**	**N/A**	**N/A**	**N/A**	**0.12**	**N/A**
	SD	**N/A**	**N/A**	**N/A**	**N/A**	**0.02**	**N/A**

Table 19. Tributyltin (TBT) Concentrations at Lundy SAC in 2017 and 2012 (Dry Wt, ng g^{-1}) (© Natural England and Cefas 2022).

Year	Station	Tributyltin (TBT; ng g^{-1})
2017	LUND01	2.59
	LUND04	<1.00
	LUND08	<1.00
	LUND09	1.80
	LUND13	<1.00
2012	NE LUN 01	<3.00
	NE LUN 02	<3.00
	NE LUN 03	<3.00
	NE LUN 04	<3.00
	NE LUN 05	<3.00
	NE LUN 06	<3.00
OSPAR EAC		**5.00-50.00**

3.3 Objective 3: Conduct a spatial comparison of intensely sampled boxes within different fisheries management zones

A total of 60 samples were used in the spatial comparison of intensively sampled boxes within different fishery management zones. Five replicate samples were collected from each of 12 stations across zones 1, 2 and 3 (Section 2.1).

3.3.1 Sediment particle size and EUNIS habitat classes

The sediment composition of the samples taken from the intensively sampled boxes across the fishery management zones varied widely. Sediments of the intensively sampled boxes of Zone 1 were represented by ‘A5.1 Sublittoral coarse sediment’ at all replicates sampled at three stations, while all five replicates of the remaining station were classed as ‘A5.2 Sublittoral sand’. The greatest spatial variability was observed across samples within Zone 2, where all four EUNIS Level 3 habitat classes were observed across the samples (Figure 25; Table 20). Samples from

Zone 3 spanned ‘A5.1 Sublittoral coarse sediment’, ‘A5.3 Sublittoral mud’ and ‘A5.4 Sublittoral mixed sediments’ (Figure 25). The variability in sediment composition within zones was derived from both between-station (box) variability and within-station (small-scale) variability, depending on the zone. Habitat class variability in Zone 1 resulted from one station (LUND31) possessing different sediments from the other stations within this zone: there was no within-station variability for this zone (Table 20). Meanwhile, habitat variability for zones 2 and 3 originated from within-station (three habitats were observed within LUND39; Zone 2) and between-station variability (LUND15 was exclusively represented by ‘A5.1 Sublittoral coarse sediment’ which was not otherwise observed in Zone 3).

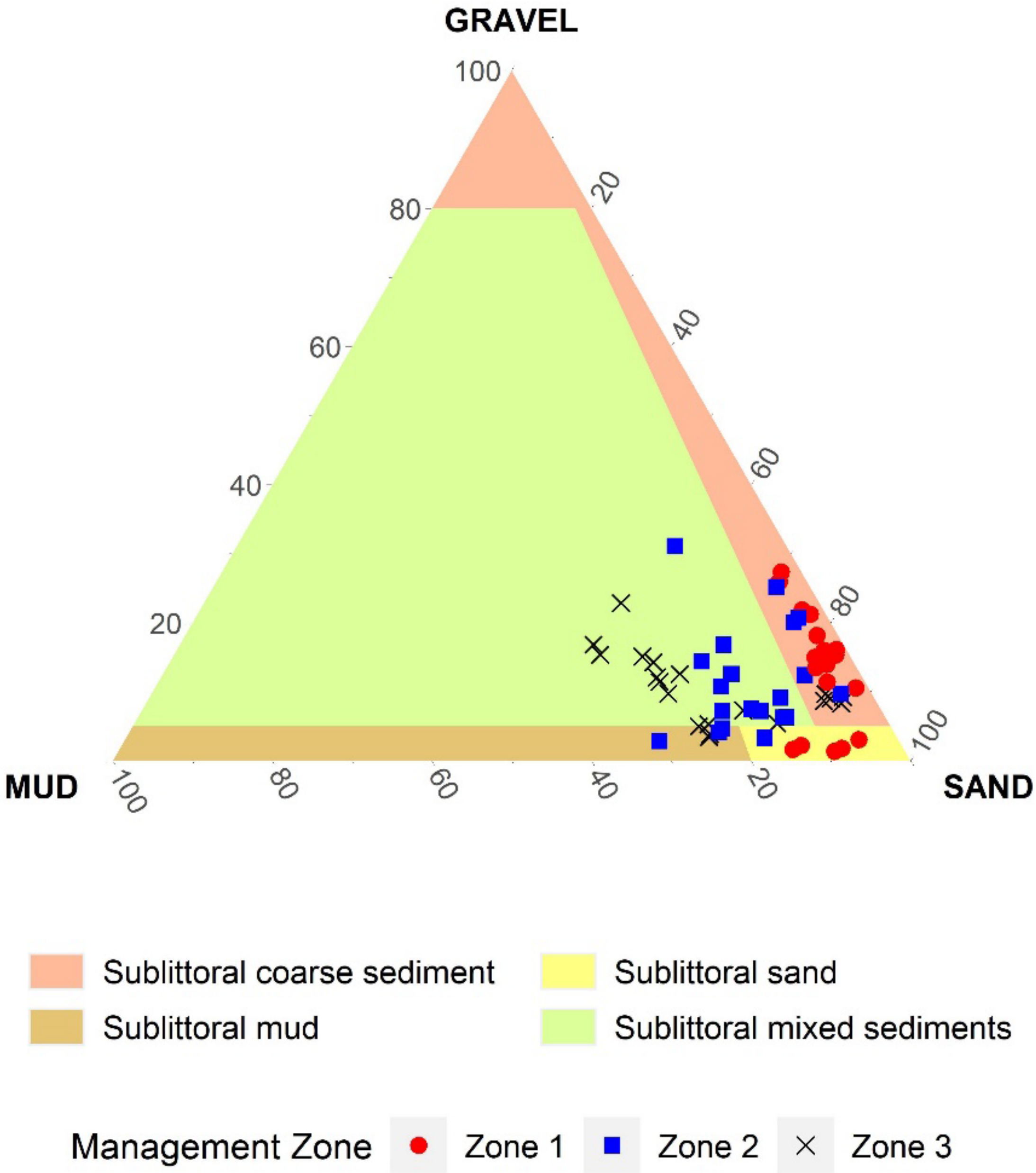

Figure 25. Trigon plot showing the composition of the sediments sampled in the intensively sampled boxes at Lundy SAC 2017 according to mud, sand and gravel components (© Natural England and Cefas 2022). Stations are coloured according to fishery management zones. The delineations between the sediment compositions of the four subfeatures are identified.

Table 20. Variations in the sediments of the five replicate samples from the intensively sampled boxes in each of the three fishery management zones (© Natural England and Cefas 2022). The number of replicates (of five) from each EUNIS habitat class are shown.

Zone	Station	‘A5.1 Sublittoral coarse sediment’	‘A5.2 Sublittoral sand’	‘A5.3 Sublittoral mud’	‘A5.4 Sublittoral mixed sediment’
Zone 1	LUND30	5	0	0	0
	LUND31	0	5	0	0
	LUND32	5	0	0	0
	LUND56	5	0	0	0
Zone 2	LUND36	0	0	0	5
	LUND39	0	1	2	2
	LUND48	5	0	0	0
	LUND55	0	0	1	4
Zone 3	LUND05	0	0	0	5
	LUND08	0	0	1	4
	LUND10	0	0	2	3
	LUND15	5	0	0	0

3.3.2 Infauna

At the scale of each station, the infaunal assemblages display significant spatial variability both within and between zones (Figure 26; with more detailed data are provided in Appendix 7). Most notably, in Zone 3, one station (LUND15) possesses species richness and total abundance statistically higher than those of the remaining three stations, whose values are comparable, in Zone 3. Similarly, in Zone 1 there are marked differences in mean species richness across all four intensively sampled boxes: this spatial variability being almost as marked in the remaining univariate metrics and total biomass in this zone. While between-station variability is less evident in Zone 2, species richness of LUND39 is statistically less than that of LUND48.

At the scale of the fishery management zone, this small-scale variability is subsumed and the result is minimal differences between zones in terms of univariate metrics and total biomass (Figure 27; see Appendix 7Appendix 6). The associated variability, as evidenced by the 95 % confidence intervals, is notable but no significant difference between zones is evident despite some differences between means being apparent. There was no significant difference in the number of taxa (*S*) (Kruskal-Wallace H = 2.7, p = 0.26, df = 2), total abundance (*N*) (Kruskal-Wallace H = 1.5, p =

0.46, df = 2), Pielou’s species evenness (j’) (Kruskal-Wallace H = 4.8, p = 0.1, df = 2) or total biomass (g) (Kruskal-Wallace H = 1.4, p = 0.49, df = 2) (Figure 27) between the three zones.

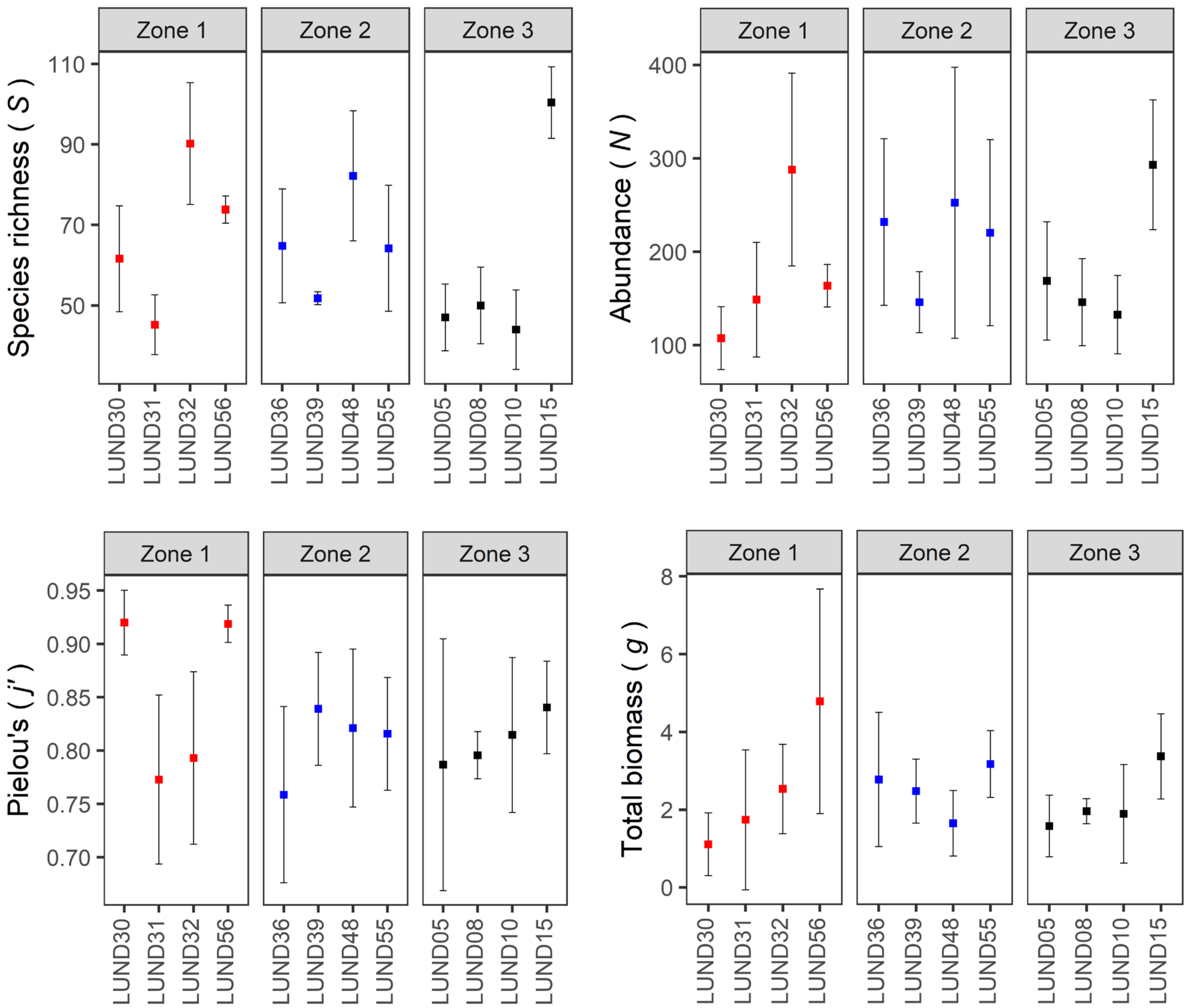

Figure 26. Mean (± 95% confidence interval) species richness (number of taxa 0.1 m^{-2}), abundance (total number of individuals 0.1 m^{-2}), Pielou's evenness (per grab) and total wet biomass (g 0.1m^{-2}) of each station across each of the intensively sampled boxes in each of the three fishery management zones (© Natural England and Cefas 2022).

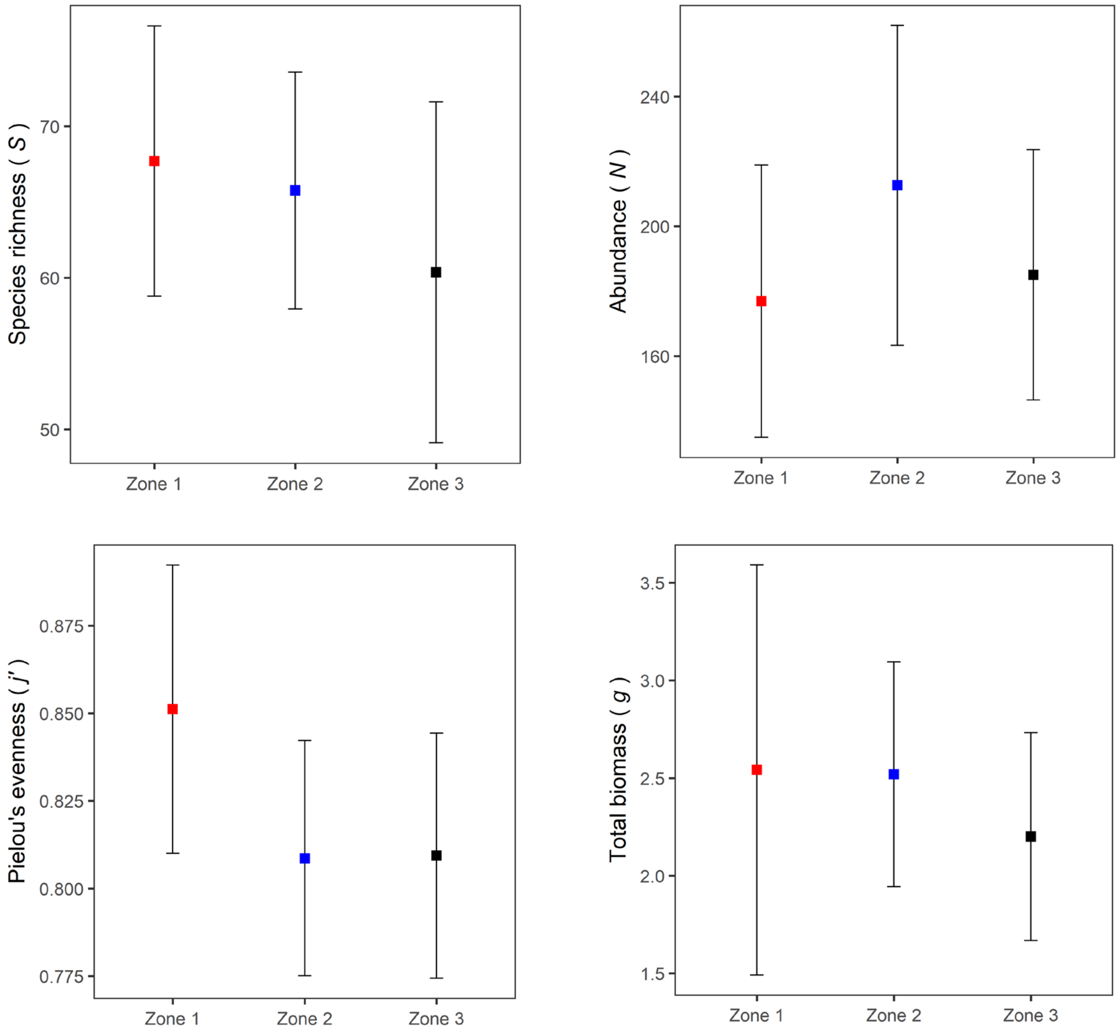

Figure 27. Mean (± 95% confidence interval) species richness (number of taxa 0.1 m^{-2}), abundance (total number of individuals 0.1 m^{-2}), Pielou's evenness (based on data from a 0.1 m^2 grab) and wet biomass (based on data from a 0.1 m^2 grab) of the replicate stations sampled across each of the three fishery management zones (© Natural England and Cefas 2022).

The variation observed between intensively sampled boxes regarding univariate metrics is also evidenced in terms of multivariate assemblage structure. When the samples are ordinated in multivariate space (Figure 28), it is apparent that while differences exist between zones (ANOSIM global $R = 0.32$, $p < 0.01$), there is notable dissimilarity in the assemblages within zones and that this is primarily, for each Zone, due to one of the four boxes harbouring distinct assemblages from the others in the Zone (Figure 28). Pairwise comparisons revealed that the greatest assemblage structural difference was between in Zone 3 and Zone 1 (ANOSIM R statistic = 0.47; Table 21). SIMPER analysis revealed that this separation was generally due to increased abundances of bamboo worms (Maldanidae) and *L. cingulata* agg. (an annelid worm) in assemblages of Zone 3, while higher numbers of the pea urchin *E. pusillus* and the clam *Spisula* spp. were recorded in Zone 1. Zones 2 and 3 generally had higher numbers of the annelid worm *M. fragilis* and the clam *Corbula gibba* than Zone 1. The results of the SIMPER analysis are provided in Appendix 7.

Table 21. Results of ANOSIM tests of differences in infaunal assemblage composition between the three fishery management zones, sampled with multiple replicates at Lundy SAC in 2017 (© Natural England and Cefas 2022).

Fishery management zone comparison	R statistic	Significance (p value)	Average % similarity (SIMPER)
Zone 3 & Zone 1	0.47	<0.01	25.60
Zone 3 & Zone 2	0.13	0.01	32.20
Zone 1 & Zone 2	0.37	<0.01	28.40

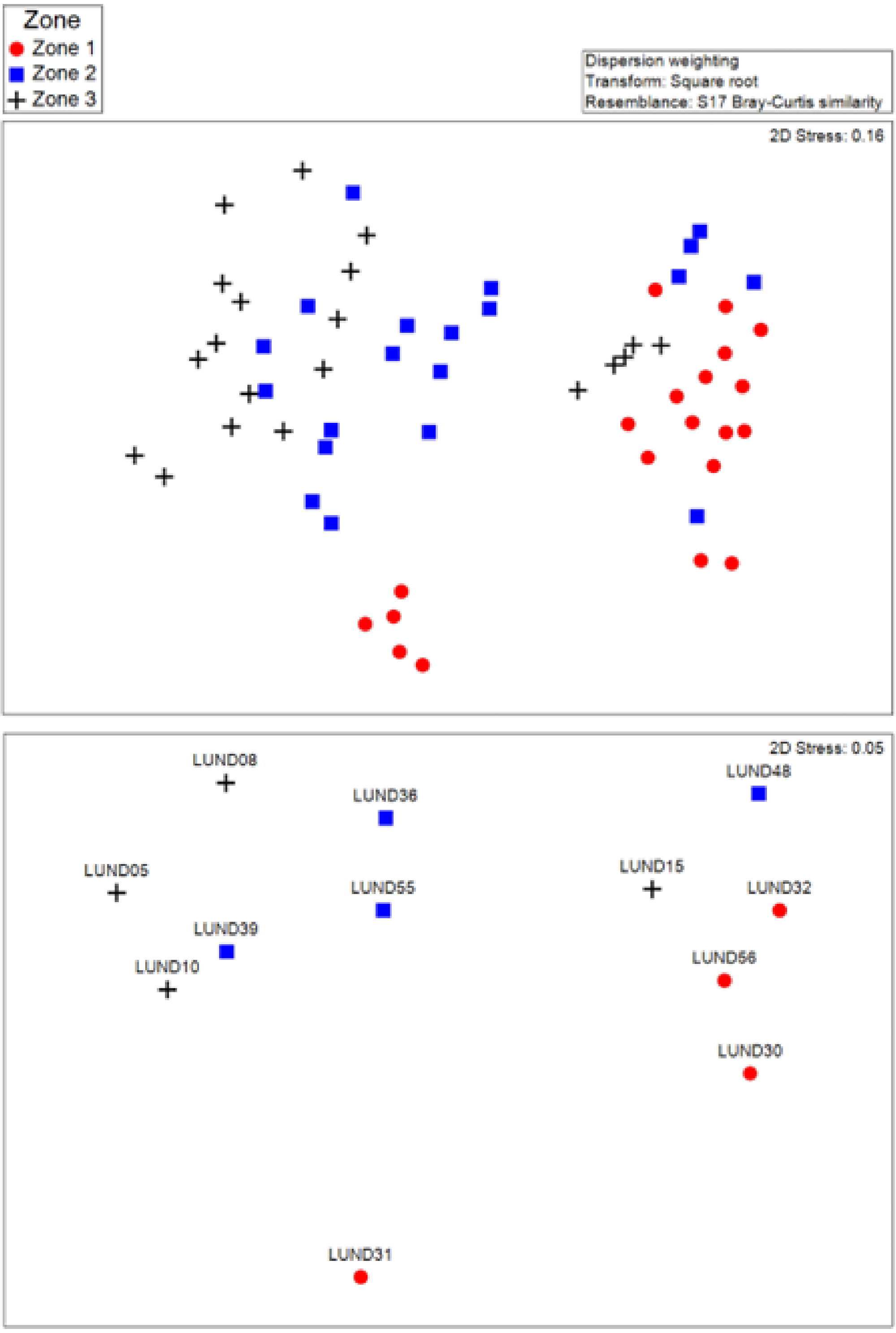

Figure 28. Non-metric Multidimensional Scaling ordination of the Bray-Curtis resemblance matrix from the dispersion weighted, square root transformed infaunal abundance data from the intensively sampled boxes at Lundy SAC, 2017 (© Natural England and Cefas 2022). Top panel shows all replicates, lower panel represents replicate-averaged data. Stations are coloured according to fishery management zone. The stress value of 0.16 in the top panel indicates that the plot should only be used to derive broad trends in the data, while the bottom panel gives an excellent representation with no prospect of misinterpretation.

3.4 Objective 4: Evaluate wider spatial variability within and across fisheries management areas.

A total of 50 stations were used to assess the spatial variability of sediment particle size and infauna within and across the fisheries management areas, based on a single sample approach. Thirty eight of these were from the single sample stations acquired across the SAC (Figure 4), while the remaining 12 comprised a randomly selected replicate from each of the intensively sampled boxes reported previously (Section 3.3; Figure 29).

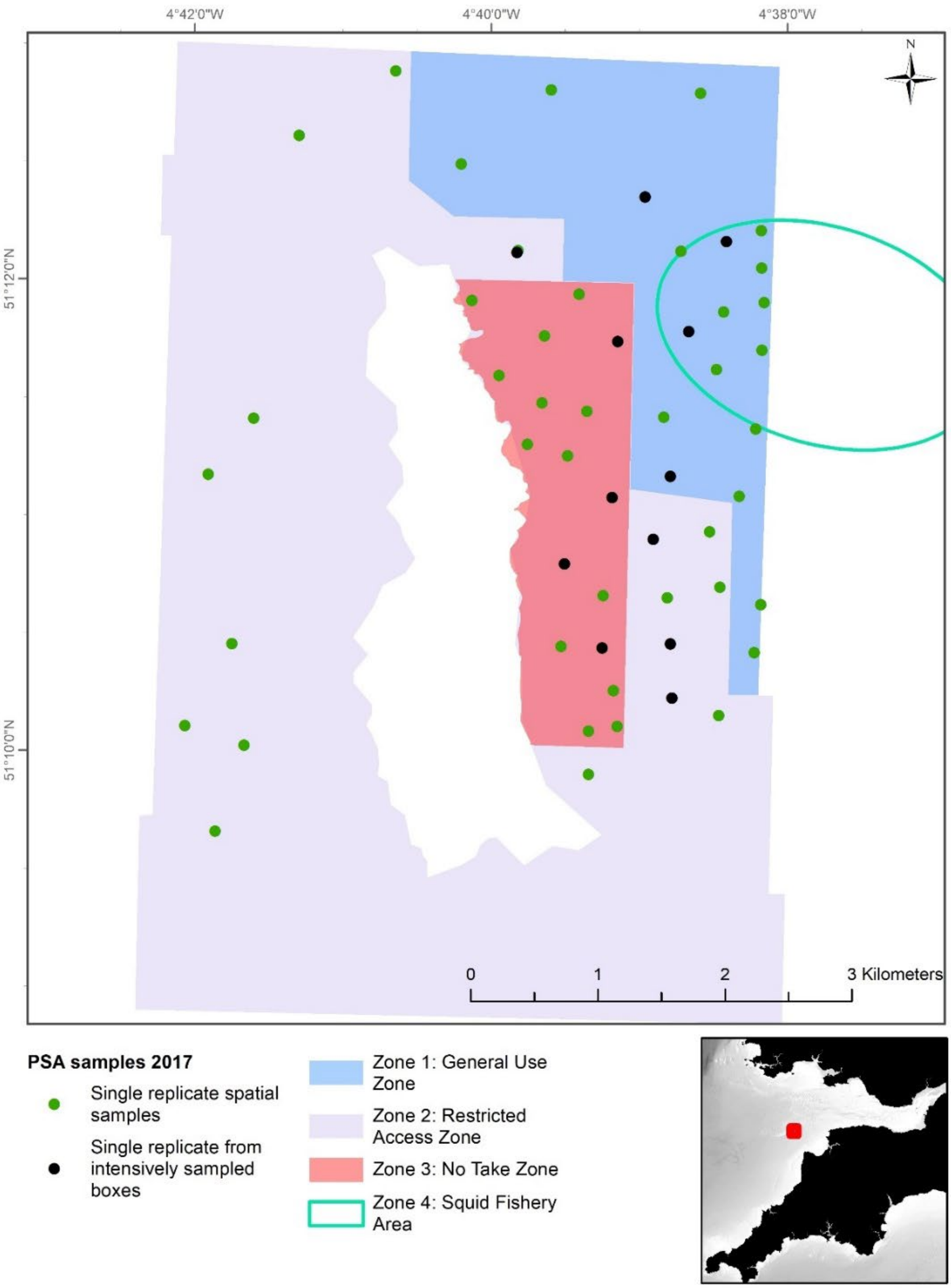

Figure 29. Location of the 50 2017 grab samples used to address Objective 4.

3.4.1 Sediment particle size

As observed based on the intensively sampled boxes (Section 3.3), the sediments in each of the zones belonged to more than one habitat class (Figure 30). Zone 1 was mainly represented by 'A5.1 Sublittoral coarse sediment', while samples from zones 2 and 3 were more variable, particularly Zone 3 where sediments were represented by all four EUNIS habitat classes. However, the variability in sediment PSA was not as marked as the delineation into four classes infers with the majority of stations possessing a dominance of sand with minor proportions of mud and/or gravel (Figure 30).

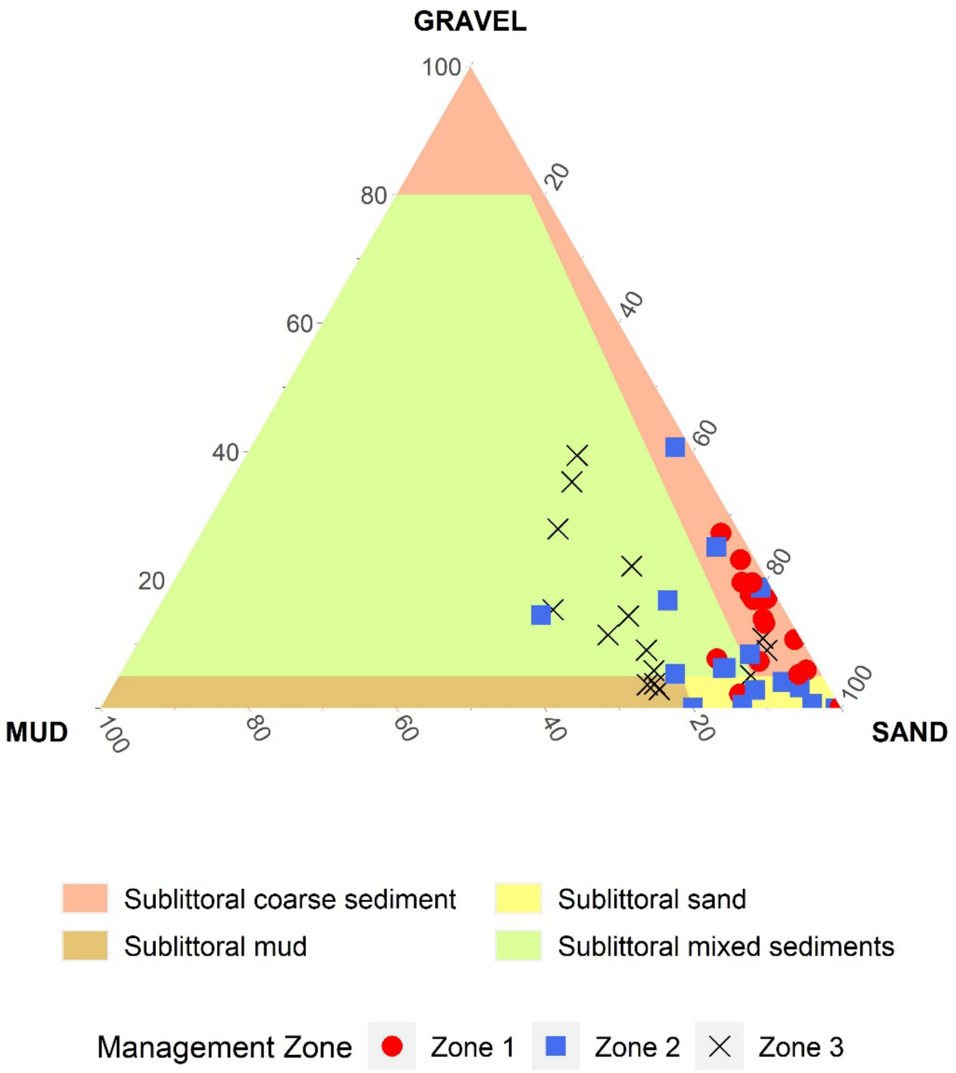

Figure 30. Trigon plot showing the composition of the sediments sampled at single stations at Lundy SAC 2017 according to mud, sand and gravel components (© Natural England and Cefas 2022). Stations are coloured according to fishery management zones. The delineations between the sediment compositions of the four EUNIS Level 3 habitat classes are identified.

3.4.2 Infauna

There was no significant difference between zones for any of the infaunal metrics assessed (Figure 31; see Appendix 8 for detailed data for each metric). While some differences in mean values are evident (e.g. S and N are lowest in Zone 3; j' is lowest in Zone 2), the lack of significant differences following statistical testing is heavily governed by the large within zone variability of all metrics.

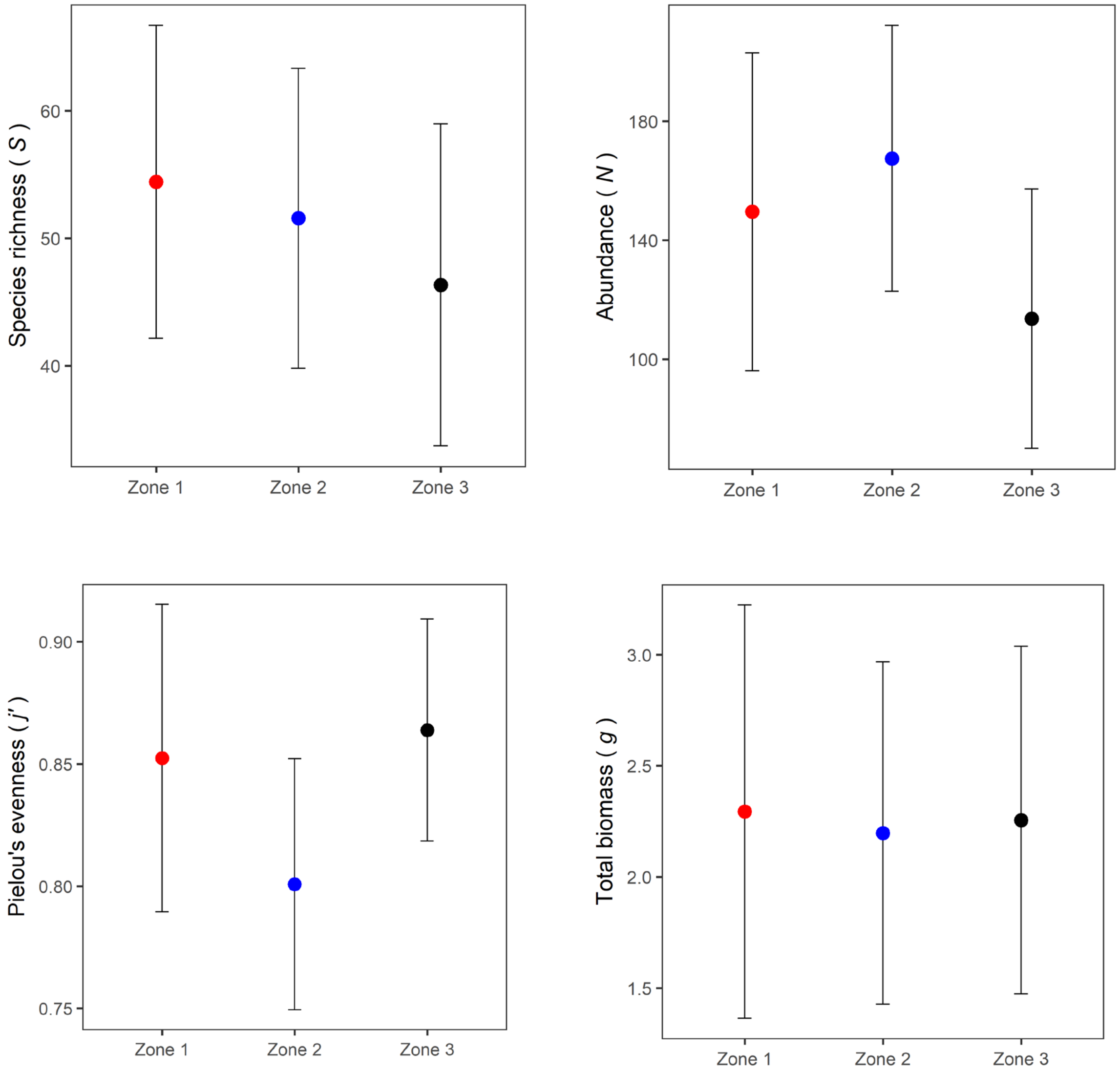

Figure 31. Mean (± 95% confidence interval) species richness (number of taxa 0.1 m^{-2}), abundance (total number of individuals 0.1 m^{-2}), Pielou's evenness (based on data from a 0.1 m^2 grab) and wet biomass (based on data from a 0.1 m^2 grab) of the single replicate stations sampled across each of the three fishery management zones (© Natural England and Cefas 2022).

Although the samples in multivariate space display no marked differentiation between management zones (possibly due to the stress value of 0.18), there was a small yet significant difference between the infaunal multivariate assemblage structure between zones ($R = 0.26$, $p < 0.01$). Pairwise comparison ANOSIM tests (Table 22) supported the nMDS ordination plot (Figure 32) revealing that the assemblage structure of samples in Zone 3 was most different to that of samples in Zone 1. SIMPER analysis revealed that assemblage differences in zones were due to the same taxa as that observed based on data from the intensively sampled boxes (reporting Objective 4) (Appendix 8). That is, Zone 3 displayed greater numbers of bamboo worms (Maldanidae) and the annelid worm *L. cingulata* agg., whereas Zone 1 displayed greater numbers of the annelid worms *G. lapidum* agg. and *Scalibregma inflatum*. However, the zones share many common abundant taxa which infers that all samples represent the same broad assemblage.

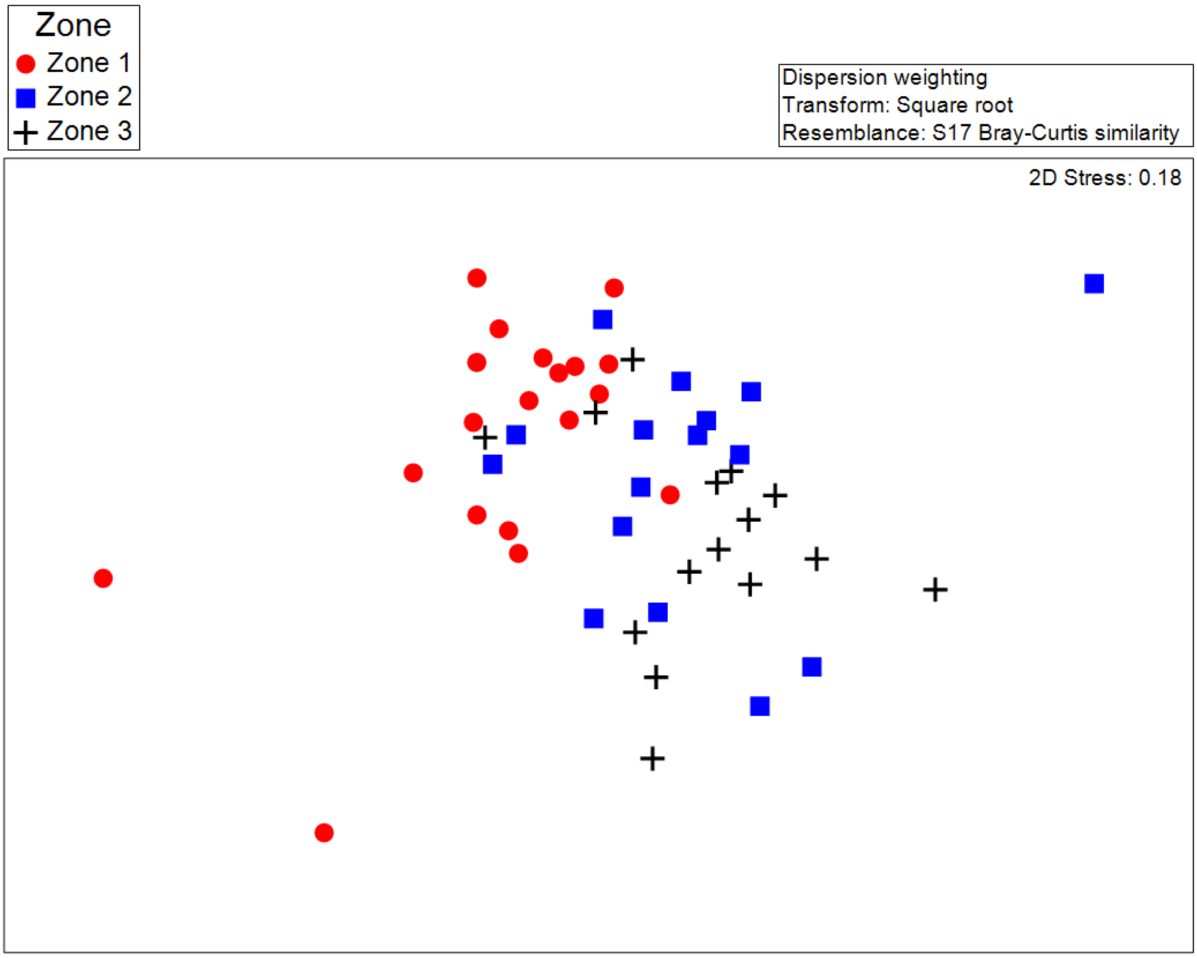

Figure 32. Non-metric Multidimensional Scaling ordination of the Bray-Curtis resemblance matrix from the dispersion weighted, square root transformed infaunal abundance data from the single replicate stations sampled at Lundy SAC, 2017 (© Natural England and Cefas 2022). The stress value of 0.18 indicates that the plot should only be used to derive broad trends in the data.

Table 22. Results of ANOSIM tests of differences in infaunal assemblage composition between the three fishery management zones, sampled with single replicates at Lundy SAC in 2017 (© Natural England and Cefas 2022).

Comparison	R statistic	Significance (p value)	Average % similarity (SIMPER)
Zone 3 and Zone 1	**0.42**	**<0.01**	18.20
Zone 3 and Zone 2	0.12	0.01	22.80
Zone 1 and Zone 2	**0.22**	**<0.01**	20.60

3.5 Objective 5: Comparison of spatial variability between intensively sampled boxes approach with that from wider sampling.

This objective compares the sampling approaches investigated in Objectives 3 (intensively sampled boxes) and 4 (single replicate samples), to evaluate potential survey designs for future monitoring.

3.5.1 Sediment particle size

The coefficient of variability of the three major sediment granulometric groups (i.e. % mud, % sand, % gravel) revealed that variability was greater based on the single sample, spatial approach (the focus of Objective 4) compared to that using the intensively sampled boxes (Objective 3) (Figure 33). However, this was zone dependent as although this effect of sampling design was consistent across zones for sand and gravel, mud content was slightly less variable in Zone 3 based on the single sample approach. While no statistically significant differences are observed between the two approaches for any of the three sediment components (based on the overlap of the confidence interval error bars), the differences in the observed means have applied implications (see Section 4: Discussion).

3.5.2 Infauna

The increased variability in sediment components between samples based on the single sample, spatial approach (Section 3.4) is mirrored in the variability of univariate metrics of community structure and total biomass (Figure 34). Again, the magnitude of this difference is zone specific. Little difference was observed in variability of total abundance in Zone 2 and total biomass for Zone 1. While no statistically significant differences (based on the overlap of the confidence interval error bars) are observed between the two approaches for any of the univariate metrics, the differences in the observed means have, as for sediment particle size, applied implications (see Section 4: Discussion).

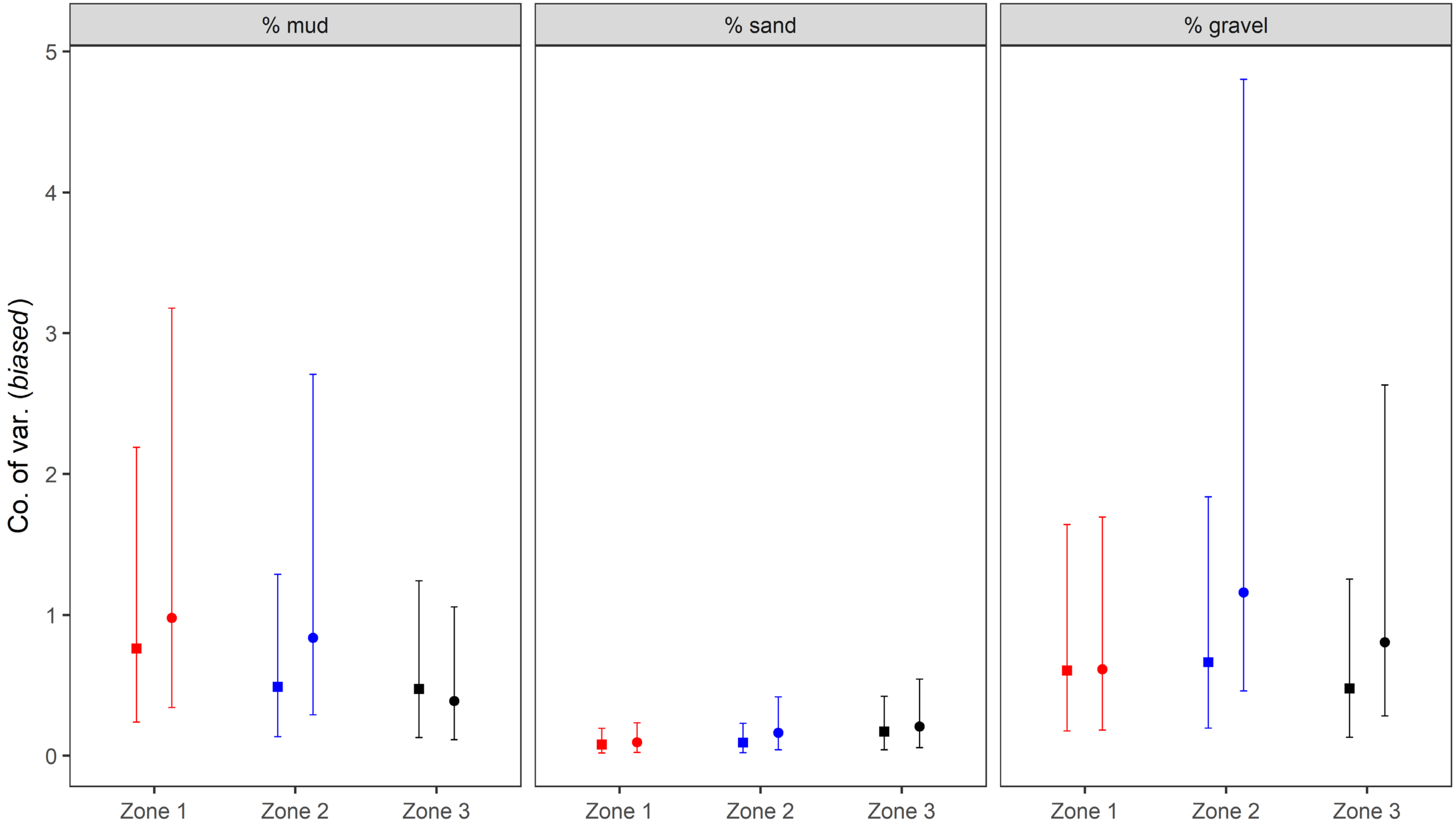

Figure 33. Mean (± 95% CI) coefficient of variability of percentage mud, sand and gravel of the sediments sampled from the stations across the three fishery management zones (© Natural England and Cefas 2022). Squares represent data from the intensively sampled boxes (n = 60) and circles are from the spatial single replicates (n = 50).

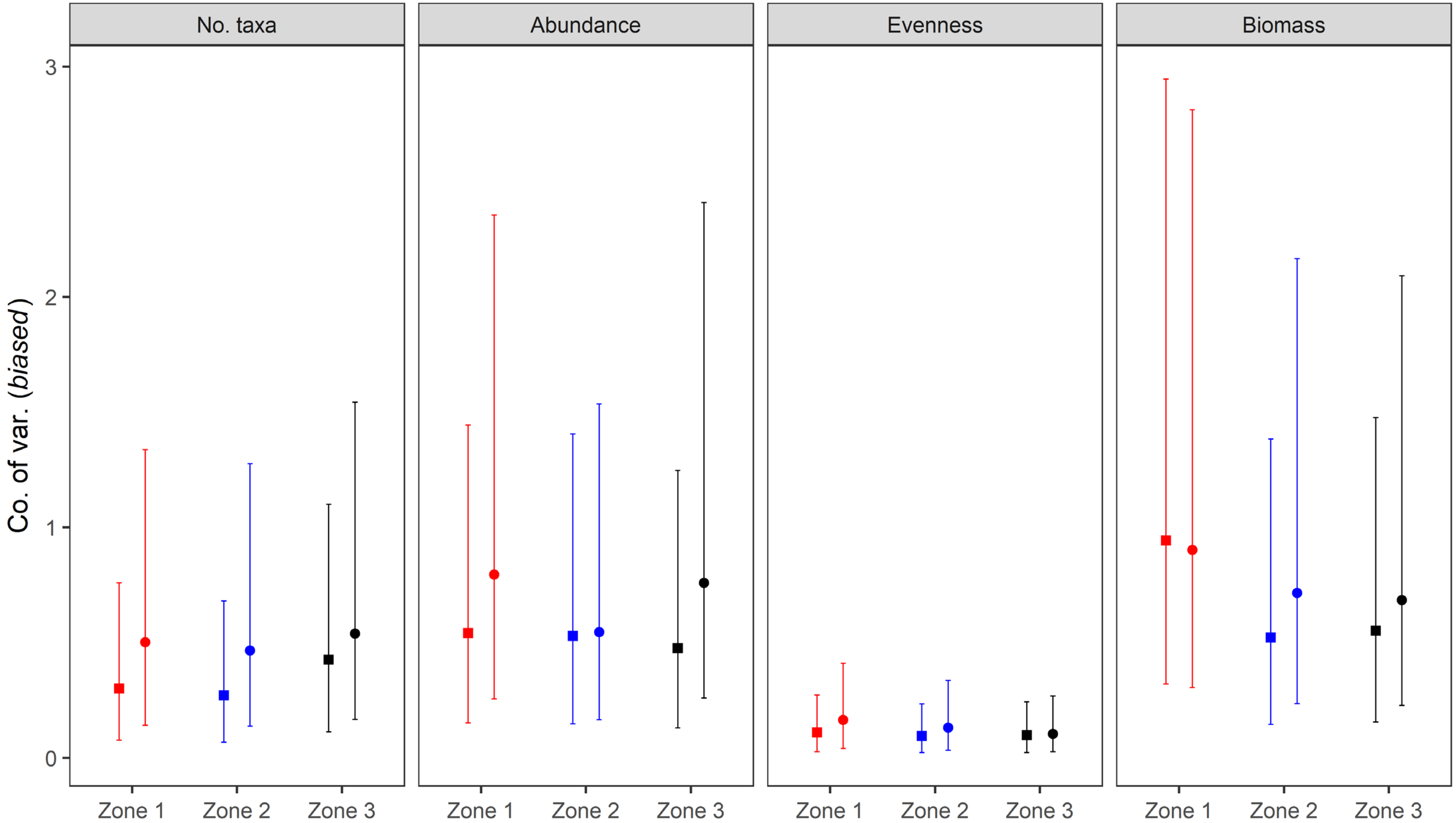

Figure 34. Mean (± 95% CI) coefficient of variability of univariate metrics of infaunal community structure of the stations sampled across the three fishery management zones (© Natural England and Cefas 2022). Squares represent data from the intensively sampled boxes (n = 60) and circles are from the spatial single replicates (n = 50).

3.6 Objective 6: Produce geomorphological and sediment map for the region of Lundy SAC where acoustic data exist.

The geomorphological map for Lundy, based on the 2015 acoustic data and the 2017 PSA data, is presented in Figure 35. The area mapped is a rectangle 4.5 km along the north-northwest to south-southeast trajectory, and spans 1.4 km at its widest, along the east of Lundy. A low (~10 m high), broad (more than 1.2 km) sandbank occupies most of the area apart from the southern section where bedrock is observed cropping out. The bedrock is upper Devonian-lower Carboniferous Pilton shales, it appears as a well-layered succession, trending approximately east to west, gently folded and fractured. A series of ~2 m tall and 50 m wide sandwaves flanks the western side of the sandbank from south to north. They present almost symmetrical profiles, with the stoss side directed northwards. The sandbank is shallow (20 m depth) in the central part of the surveyed area, and slopes to 35 m depth in the north where PSA samples collected in 2017 indicate coarser grain sizes. In the deeper water in the north the seabed is distinguished by pervasive mega-ripples that appear to indicate south-westward migration. In the north-western corner of the area, a knobbly and irregular surface suggests the presence of sub-cropping bedrock.

Sedimentological predictions, based on a random forest model trained using the 2017 PSA data, are presented in Figure 36. Cross-validation of the random forest model applied to predict benthic community assemblages found an overall accuracy of 72.7 % (Table 23). Coarse sediment is prevalent in the northern part of the sandbank, where extensive rippling is observed. Featureless sand and mud dominate the central-eastern portion of the MBES data, corresponding to the flat top of the sandbank, possibly suggesting lower current energies at the seabed. Apart from the bedrock outcrops, the rest of the seabed is characterised by mixed sediments. A comparison of the map with the PSA samples from 2012 (Figure 36) shows some differences in 50 % of cases, with two samples being coarse instead of mixed sediments and one sample being mixed instead of coarse sediment. While this suggest some variability, it is not sufficiently significant to indicate wide changes of superficial sediment distribution across the mapped area.

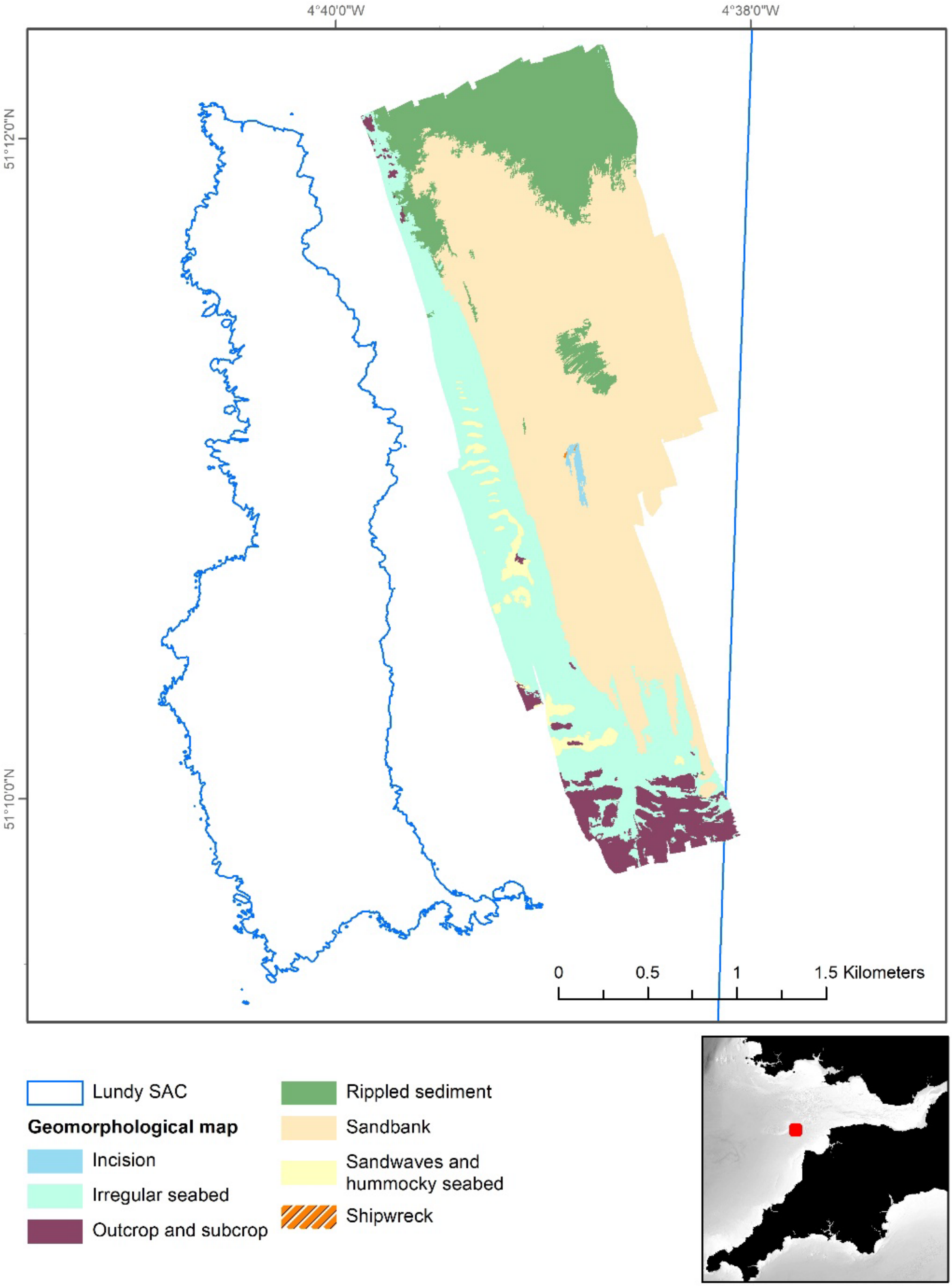

Figure 35. Results of the geomorphological mapping based on the acoustic data derived at Lundy SAC in 2015.

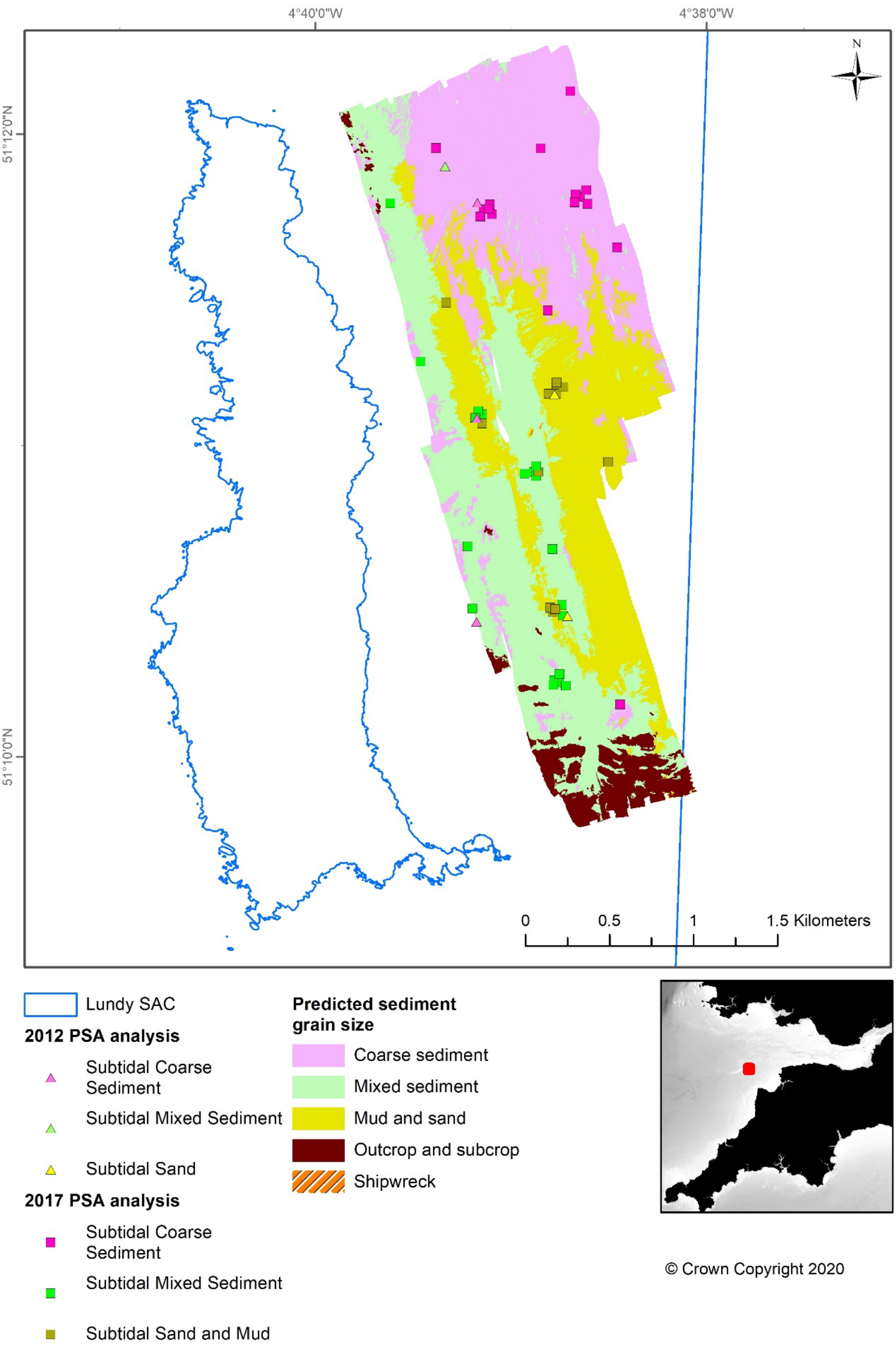

Figure 36. Results of the sedimentological predictive mapping. PSA groundtruthing data from both 2012 and 2017 are shown on the map, suggesting some changes in superficial sediment composition.

Table 23. Combined error matrix for sedimentological classes within the mapped area using samples withheld for cross-validation (© Natural England and Cefas 2022). Fine – Sublittoral sand and mud, Mixed – Sublittoral mixed sediment, Coarse – Sublittoral coarse sediment. No assessment of accuracy has been made for the two geomorphic classes (bedrock and subcrop and shipwreck), which were not directly sampled for PSA analysis.

		Observed			User's accuracy
		Fine	Mixed	Coarse	
Predicted	Fine	1	0	1	50%
	Mixed	1	4	1	66%
	Coarse	0	0	3	100%
Producer's accuracy		50%	100%	60%	Overall accuracy = 72%

3.7 Objective 7: Compare the abundance and distribution of NIS between 2007, 2012 and 2017

Based on the grabs sampled at the Lundy SAC, observations of NIS recorded during each of the three surveys (2007, 2012 and 2017) are represented spatially in Figure 37. One individual of the barnacle *Hesperibalanus fallax*, which is included on the MSFD list (Annex 2), was identified from a single grab sample collected in 2012 (LUN 11D). Three taxa not on the MSFD list but included in the JNCC report (Eno *et al*., 1997) were also found at the Lundy SAC in 2012. In 2017, the annelid worm *Goniadella gracilis* was identified in sediment samples collected from ten of the 50 stations surveyed. The occurrence of this species in Britain was reported in 1972 and it may now be considered naturalised (Walker, 1972). The crustacean *Monocorophium sexotonae* was found at one and four stations surveyed in 2007 and 2012, respectively. Another crustacean, the barnacle *Austrominius modestus*, was noted to be present from a single occurrence at one station (Lundy 41, south-east of Lundy) sampled in 2007. No NIS taxa were recorded from the imagery data acquired in 2017.

The surveys reported here were not designed to specifically monitor (or identify the presence of) the full list of marine (planktonic, benthic, epibenthic) NIS. As such, an absence of certain species within the data presented here should not inherently be interpreted as an absence from the site. Further, while the data for three survey years are presented in this section, no attempt at evaluation of temporal change should be made, due to inconsistencies in both the survey designs (number and location of samples) and the survey approaches (differences in gear types).

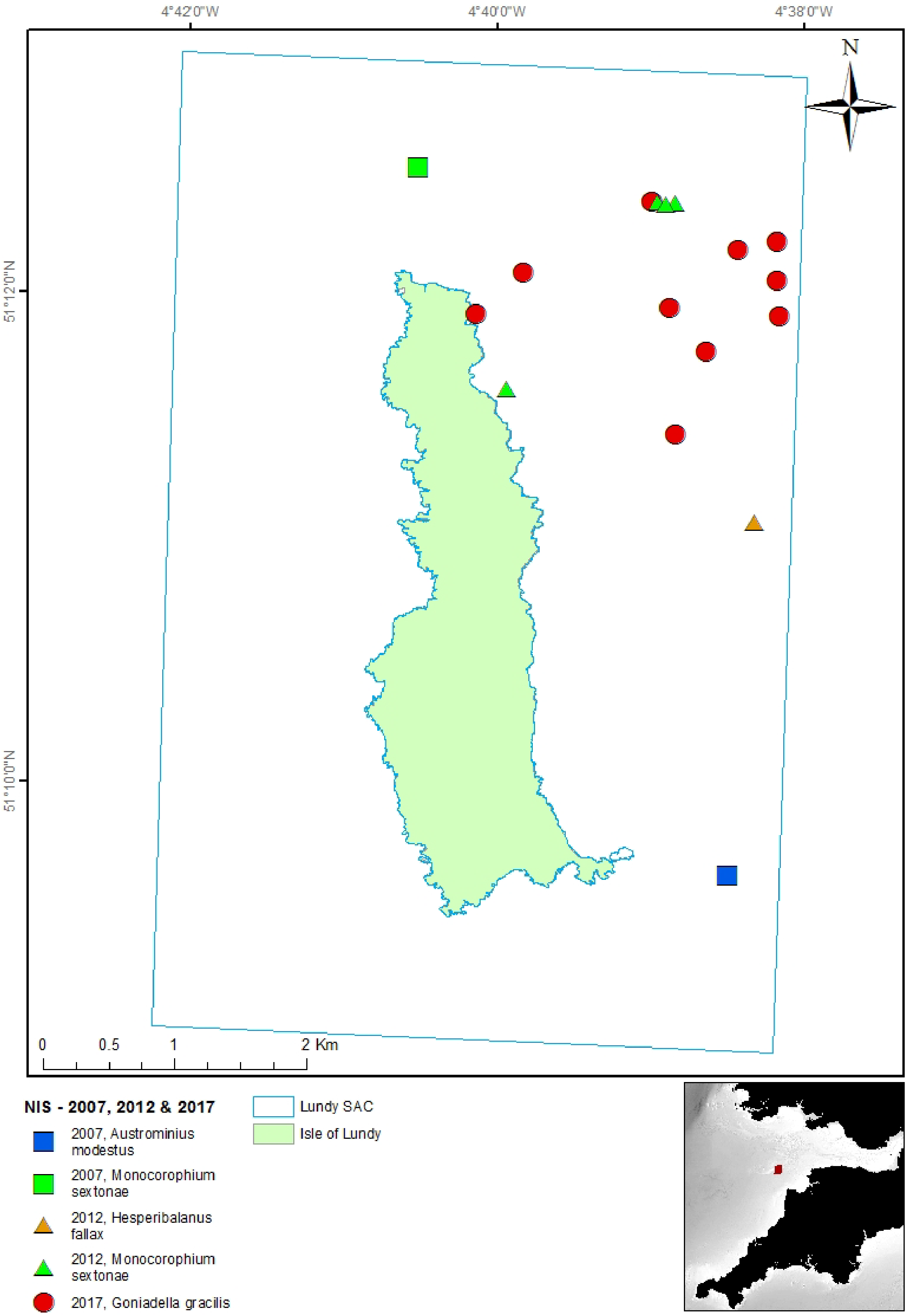

Figure 37. NIS recorded in sediment samples acquired from Lundy SAC in 2007, 2012 and 2017 (© Natural England and Cefas 2022).

3.8 Objective 8: Note observations of any Habitat or Species FOCI not covered by Designation Order as features of the site

Although still images alone are generally not sufficient in assigning a habitat FOCI to a station, where they represent the only data available and are aggregated as in this study, they offer some use in providing an indication of FOCI presence. The habitat FOCI ‘Sublittoral sands and gravels’ was identified from two segments of the seabed video imagery at GT10_STN_12. Although this FOCI was also observed in two still images at GT11_STN18, these data are insufficient in themselves to assign this habitat FOCI to this station. No species FOCI were observed in the samples collected for benthic infauna, nor were any observed during analysis of the epibiotic data from the 2012 and 2017 surveys of the Lundy SAC.

The surveys reported here were not designed to specifically monitor (or identify the presence of) all species FOCI. As such, this should not be interpreted as an absence of these species from the site.

3.9 Objective 9: Present evidence relating to marine litter (Descriptor 10), to satisfy requirements of the Marine Strategy Framework Directive

There was no assessment of litter from the sediment samples collected in 2007 and 2012. The presence of four categories of litter (Annex 3) was determined from the sediment samples collected for infaunal analysis during 2017, these data are reported in Green and Johnson (2020). In brief, from the 98 samples collected, 81.60 % were found to contain litter >1 mm, with a mean of 5.53 (0.92 ± S.E) particles per sample, with the most frequent litter type encountered being the category A14 microbeads (Green and Johnson, 2020).

No video footage or stills images were collected during the 2007 or 2012 surveys. No occurrences of litter were recorded from analysis of the 2017 seabed imagery data.

4 Discussion

This discussion presents advice for future monitoring of designated features of the Lundy SAC, as required to achieve the report objectives stated in Section 1.4.2. Report Objective 1 requires the description of a sub-set of feature attributes (Table 3) selected from SACO for the site. This objective is discussed below in Section 4.1**Error! Reference source not found.**. Evidence of non-designated habitats and species FOCI to satisfy report Objective 8, NIS and marine litter (report objectives 7 and 9 respectively) is also discussed in this section. Further, the outcomes of the interpretation of the opportunistically acquired acoustic data during 2015 (report Objective 6) for the creation of a geomorphological and sediment map is also discussed in Section 4.1. Report Objective 2, which focusses on a temporal assessment of sediment nutrients and contaminants, is discussed in Section 4.2. Finally, a discussion of the comparative merits of adopting each of the two fundamentally different survey approaches; multiple replicates at a small number of stations (i.e. intensively sampled boxes) or single samples across a wider spatial area (report Objectives 3, 4 and 5), is presented in Section 4.3.

4.1 Benthic and environmental overview

The grab and imagery survey conducted across the Lundy SAC during the summer of 2017 successfully acquired data of sufficient scientific robustness, and quality to describe the infaunal and epibiotic assemblages across the entire SAC and of its designated features. One of the most notable observations is the site's diversity; a total of 472 taxa were sampled from the 98 grab samples alone, with a further 66 morpho-taxonomic entries from the 199 still images analysed. It is likely that additional epibiotic taxa would have been observed if the video imagery had been of greater quality, allowing a more reliable analysis.

Four sedimentary EUNIS Level 3 habitats were reported from the grab samples; stations representing the two Annex I Sandbank habitats ('A5.1 Sublittoral coarse sediment' and 'A5.2 Sublittoral sand') were sampled, while a significant number of stations (38 of the 98) represented 'A5.4 Sublittoral mixed sediments'. In broad terms, the sediments appear to be coarser in the north-east of the SAC, they then transition southwards through to sandy sediments before becoming mixed in the south-east with areas of Annex I Reef. The geomorphological and sediment maps produced for a limited extent of the eastern side of the SAC, based on MBES data previously acquired during 2015, revealed that this region is comprised mostly of a sandbank, with areas of outcropping bedrock towards the south-east, as validated by a limited number of adjacent (not coincident) imagery stations. The sedimentary areas on the western side of Lundy are predominantly sandy, with a significant number of seabed imagery stations indicating extensive bedrock and boulder reef close to the western shore of Lundy, as previously mapped based on data acquired during 2007 (i.e. the Open Data Habitat Map) and further supported by the 2017 data

(Figure 19). The seabed of the Lundy SAC is, therefore, very varied, both in terms of its sediments and its rocky substrata, but also with respect to the spatial heterogeneity created by the interspersion of the two.

The ‘A5.1 Sublittoral coarse sediment’ of the Annex I Sandbank was notably diverse, comprising an increased number of solitary and colonial taxa generally not observed in the other sediment habitats across the Lundy SAC. In terms of taxonomic structure, this habitat was significantly different from those of the other three sediment habitats sampled. The other Annex I Sandbank habitat, ‘A5.2 Sublittoral sand’, was noteworthy in that it harboured particularly low numbers of taxa, numbers of individuals and total infaunal biomass.

Limitations in the extent of useable seabed video data across a site which has historically been characterised (through diver studies) by extensive kelp forest means that caution must be applied to the stills based epifaunal analysis used in this study when using the derived assemblages as part of a T0 monitoring dataset. However, the use of image agglomeration across identified ‘sub-segments’ adopted here has provided imagery samples which have a degree of consistency across the area.

Indicator species, as derived from the IndVal metric in the Multipatt analysis, can be used to reflect the ecological (abiotic and biotic) preferences of the clusters they are indicative of, according to the ecological niche concept (De Caceres *et al.*, 2012). Indicator metrics have been shown to be effective in defining depth-related zonation of marine epifaunal communities (Heyns *et al.,* 2016). The epibiotic data for Lundy show that that the IndVal derived indicator species reflect the expected ecological niches of their epibiotic clusters. The epibiotic communities observed from the cluster analysis and subsequent derivation of indicator taxa (Multipatt analysis with IndVal metrics) were associated primarily with the EUNIS L3 habitats ‘A3.1’ and ‘A4.1’.

The epibiotic assemblages observed within the EUNIS L3 habitat A3.1 varied substantially between the k-means cluster groups. Further subdivision of cluster groups within the EUNIS Level 4 habitat complex A3.11 (as characterised by *Laminaria* spp. as an indicator taxon) was possible for two of the three cluster groups. The use of the L4 habitat complex ‘A3.11’ as characteristic of cluster group 1 is required due to the inability to identify which *Laminaria* species are present. There is also a notable lack of similarity between the sub-segments which comprise this assemblage (32.06%). This is indicative of the issues with the imagery data as discussed above, resulting in a difficult to determine signal for kelp communities. The EUNIS L5 biotope complex ‘A3.116’ (Foliose red seaweeds with dense *Dictyota dichotoma* and/or *Dictyopteris membranacea*) is also represented by a subsection of the epibiotic assemblages observed. The depths occupied by segments belonging to these two cluster groups are similar (between 5 and 15 m), and all three cluster groups (‘1’, ‘3’ and ‘6’) are associated with tidal magnitudes of < 0.4 m s^{-1}.

The communities associated with the EUNIS L3 habitat ‘A4.1’ were broadly characteristic of wave-exposed circalittoral rock, with indicator taxa often characteristic of the L4 habitat complexes 'A4.13' and 'A4.11'. Common indicator taxa such as *Alcyonium digitatum*, live *Tubularia indivisa*, turf forming/encrusting bryozoa, and repent /arborescent sponges were noted across the cluster groups. There was notable further division into three L5 or L6 habitats, with 'A4.1312' (Mixed turf of bryozoans and erect sponges with *Dysidea fragilis* and *Actinothoe sphyrodeta* on tide-swept wave-exposed circalittoral rock) being observed. Furthermore, two of the cluster groups were characterised as the L5 biotope complex 'A4.112' (*T. indivisa* on tide-swept Atlantic circalittoral rock) and the L6 biotope 'A4.1122' (*A. digitatum* with dense *T. indivisa* and anemones on strongly tide-swept circalittoral rock). Environmental drivers of the distribution of these circalittoral habitats are primarily depth and tidal magnitude, with the *T. indivisa* and *A. digitatum* dominated communities ('A4.112' and 'A4.1122') located primarily in depths of greater than 20 m. Cluster group 4 (defined as 'A4.112' and dominated by *T. indivisa*) is also associated with the high tidal magnitudes of the south and northern parts of the island, alongside patches of coarse substrate (with three segments classed as the EUNIS L3 habitat 'A5.1' (circalittoral coarse sediment). The sparser community defined by cluster group 2 ('A4.1122') appears functionally more suited to the slightly lower tidal magnitudes of the western shelf, being indicated by erect sessile fauna such as *A. digitatum* and branching-repent sponges which require more moderate (but comparatively high) magnitude currents to facilitate feeding but limit the potential for damage. The 'A4.1312' community is predominantly located in the more sheltered western shore of the island and appears to be an intermediary zone between the kelp-dominated infralittoral and the high energy circalittoral habitats.

A further key finding of this study is the apparent gradation of two of the high energy circalittoral biotopes ('A4.1122' and 'A4.1312' - defined from cluster groups 4 and 5) into the moderate energy biotope 'A4.212' (*Caryophyllia smithii*, sponges and crustose communities on wave-exposed circalittoral rock). Again, depth and tidal magnitude appears to contribute to the distribution of this gradation.

The epibiotic communities observed at Lundy SAC during 2017, both infralittoral and circalittoral, are considered typical for this site as they generally align with those observed in previous studies and those described in the SACO document (Natural England, 2017). However, there is a lack of resolution within the 'infralittoral kelp' ('A3.11') assemblages described herein, which may result in a reduced utility of these findings in the monitoring of change in community composition for these features (for example, the lack of *Laminaria* species identification). It is likely, however, that future extent of broad kelp community distribution can be monitored using these results. Similarly, variability within circalittoral rock communities observed (i.e. the gradation from 'A4.1' towards 'A4.2' habitats) may also impact the ability of future studies to detect change within these communities. However, the relative dominance of *T. indivisa* versus *A. digitatum* and/or repent sponges should continue to provide indication high and moderate to high tidal magnitude driven community distributions, alongside the abundance of *C. smithii* in the 'A4.1312' characterised community. Frequency of occurrence for cluster group 3 in comparison to cluster group 1 ('A3.1161 and 'A3.11') may provide indication on the extent (and perhaps the condition) of the kelp forest habitats on the western coast, as both clusters appear to occupy the same environmental niche (infralittoral moderate/low energy bedrock). The relatively impoverished red and fucoid algal community of cluster group 6 is associated (anecdotally through review of imagery) with a fine sediment veneer – leading to a reduced algal diversity and possibly to the indicative prevalence of the epiphytic bryozoan *Electra pilosa*. As this species is reported to have a low intolerance to increased suspended sediment load (Tyler-Walters, 2005), changes in the extent of this community may provide an indication of changes in suspended sediment load within the infralittoral.

Annex I Reef has been determined to be present at stations classified as both 'A3.1 Infralittoral high energy rock' and 'A4.1 High energy circalittoral rock'/'A4.2 Moderate energy circalittoral rock'. The 'bedrock' Annex I Reef subtype is associated with k-means cluster group '3', whereas other k-means cluster groups are associated with the broader 'bedrock and/or stony' Annex I Reef class. The greater number of segments within the 'bedrock and/or stony reef (potential)' class can be attributed to the lack of elevation and total extent / faunal cover data which, when available, allows for greater discrimination of reef subtypes.

4.2 Sediment nutrients and contaminants

Sediment nutrient and trace contaminants data from five of the stations sampled along the east coast of Lundy in 2017 were compared with those from six stations sampled in 2012. While the locations of the 2017 stations were not spatially coincident with those previously sampled, the data from the two years may be used to make inferences regarding the levels of these chemicals and whether any broad temporal changes are evident (excluding nutrients which were only assessed in 2017).

As one may expect, organic carbon fractions were inversely related to the relative coarse fractions of sediments, as they provide less surface area for organic particles to adsorb. Trace metals (As, Cd, Cr, Cu, Hg, Pb, Ni, Zn) are comparable with OSPAR Background Assessment Concentrations (BACs) (OSPAR, 2008). There are minimal elevations for Hg, Cr and Ni for both years, and elevations for Cu only in 2012. These concentrations reflect the natural mineralogical characteristics of this region and are consistent with regional baselines for the Severn region (Mason *et al*, 2011).

PAHs are hydrocarbons with two or more aromatic rings and are formed in the environment through incomplete combustion of organic material (pyrogenic) along with diagenesis (petrogenic) and biosynthesis (biogenic) processes (Neff *et al.*, 2011; Juntilla *et al.*, 2015). Ten PAHs were measured in the Lundy sediment samples and two compounds, benzo(a)pyrene and naphthalene exceeded one or more threshold values at all stations in both survey years (except one station in 2012). Other PAH contaminants showed greater spatial variability with exceedances at certain stations only, although the three most southerly stations sampled in both years showed no exceedances other than benzo(a)pyrene and naphthalene. Two PAHs (Benzo(ghi)-perylene, Indeno(1,2,3-c,d)pyrene) were consistently below all threshold criteria while a further two (anthracene, pyrene) displayed only one exceedance, the most northerly station assessed in 2017.

Polychlorinated biphenyls (PCBs) are toxic organochlorines, initially manufactured for use in the production of electronics, building materials and as vehicles for pesticides (Korrick and Sagiv, 2008). PCBs of seven congeners (028, 052, 101, 118, 138, 153, 180) were analysed from the Lundy sediments and the results indicated slightly decreased concentrations in 2017 compared to those of 2012. Four of the congeners in 2017 (apart from PCB118 at one station) were all below limit of detection while concentrations below the limit of detection only occurred once in 2012. However, all concentrations in both survey years were below the western North Sea reference of 2 ng g^{-1} (Sheahan *et al*., 2001).

Polybrominated diphenyl ethers (PBDE), are a group of organobromines commonly used as flame retardants in many products, including as an additive in paints, textiles and plastics. In 2012, only one PBDE (PBDE47) exceeded the limit of detection (0.1 ng g^{-1} at that time), across five of the six stations. PBDE appeared to display an increase with a mean concentration of 0.13 ng g^{-1} across all stations in 2017. However, temporal comparisons of concentrations with 2017 are problematic due to the lower limit of detection (0.02 ng g^{-1}).

Tributyltin (TBT), which was commonly used in antifouling paints prior to 2008 when a global ban was introduced for all ships (OSPAR, 2017), is a known endocrine disruptor with high persistence within the environment (O'Malley, 2010). TBT concentrations were below the limit of detection across all stations in 2012 and below detection of a reduced detection limit of 1.00 ng g^{-1} at all but two stations in 2017. All samples were below the OSPAR EAC range of 5.00-50.00 ng g^{-1} and can, therefore, be considered relatively low at the Lundy SAC.

In summary, the sediment contaminants and nutrients data for Lundy infer that the SAC does not exhibit any real concern regarding any contaminant type. The data acquired thus far form a suitable basis from which future contaminants assessments may be made, and efforts to ensure sampling (including the locations of the stations sampled) and sample processing are conducted in a comparable manner to those hitherto should be made.

4.3 Comparison of survey designs for monitoring fishery management zones

The data did not reveal any notable difference in sediment particle size or infaunal community structure between any of the fisheries management zones. Although this result may be partly due to the limited amount of fishing in the region, it was predominantly due to a large amount of spatial variability within zones. It is likely that there will be a requirement to monitor whether differences in the temporal trajectories of infaunal community structure exist as part of future monitoring programmes at the Lundy SAC, to assess whether any future changes to the levels of fishing pressure in any of the zones affect seabed assemblages. The data acquired during 2017 offer an important basis upon which a suitable design can be established to minimise the effect of spatial variability hindering the capacity of future monitoring to detect any change that might occur. Recommendations for future monitoring survey designs are provided in Section 5.

A range of survey designs exist to empirically quantify spatial and temporal variability. In the field of marine benthic ecology, such approaches generally adopt either a station-specific approach, wherein many samples are taken from within each of a number of small areas of the seabed (i.e. stations), or a single sample approach across a wider number of stations (although both approaches can be combined into one design). The data acquired based on each approach vary and each approach has advantages over the other. The ultimate choice of design should always be made based on the objectives of the survey. For the Lundy SAC, the 2017 survey comprised both approaches to allow an objective comparison of each to be conducted with respect to the fisheries management measures in place. The acquired data revealed that both the sediments and the univariate measures of infaunal assemblage structure and biomass varied both within and between zones. Such variability will ultimately affect the power to detect a change in sediment and infaunal assemblages between zones as part of a monitoring programme. The small-scale replicate approach allowed an assessment as to the spatial scale of this variability and revealed that variability exists at small spatial scales, even within the intensively sampled boxes. For example, the five replicates sampled at one station within Zone 2 (LUND39) were classed according to three different EUNIS Level 3 habitat classes (Table 20) and LUND10 in Zone 3 exhibited three replicates from ‘A5.4 Sublittoral mixed sediments’ and two classed as ‘A5.3 Sublittoral mud’. Meanwhile, small-scale variability was much less at other stations, showing a consistent categorisation of all replicates to a single subfeature type. Quantification of such small-scale variability was only achievable through this survey approach and it has revealed which stations may provide a more suitable basis for inclusion into a monitoring design and which ones (e.g. LUND39, LUND10) will result in a reduced power to detect change in extent and distribution in subfeature habitats. The information presented in this report may be used to determine the most suitable stations which future monitoring should include, and this will depend upon whether only the designated habitats of the Annex I Sandbanks feature are the focus, or whether all habitats, i.e. including ‘A5.3 Sublittoral mud’ and ‘A5.4 Sublittoral mixed sediments’, are also to be monitored.

The data revealed that significant differences existed between the intensively sampled boxes for sediment particle size and infaunal univariate measures of community structure (Objective 3, Figure 26). Such variability would ultimately confound assessments of differences between zones over time as it would lead to a decreased power to detect statistical differences. This was further evidenced in report Objective 4 where no statistical difference was observed between zones for any univariate metric based on a single sample approach (Figure 31). It is clear that Zone 1 in particular possesses appreciable variability in univariate metrics of community structure, and that the multivariate taxonomic composition of LUND31 within this zone is notably different from that of the other three stations (i.e. intensively sampled boxes) in this zone. Similarly, LUND15 within Zone 3 (where all samples represented ‘A5.1 Sublittoral coarse sediment’) possesses sediment PSA attributes very different to those of the other three stations (LUND05, LUND08, LUND10) within this zone which were classed as either ‘A5.3 Sublittoral mud’ or ‘A5.4 Sublittoral mixed sediments’ (Table 20). These data, and the scales of variability observed, need to be used in the development of a suitable survey design to be taken forward when attempting to detect changes between zones in subsequent monitoring programmes. We propose that the stations which have been shown to clearly differ from others within each zone be removed from further monitoring to increase the statistical power to detect any subsequent change should a Before-After-Control-Impact (BACI) design be considered.

5 Recommendations for Future Monitoring

Decisions regarding the design of any monitoring survey, and the specific approaches (e.g., gear types) adopted, should ultimately be strictly governed by the specific aims and objectives of the survey. While it is not possible to fully anticipate the aims of the future monitoring at the Lundy SAC at the time of writing, the insights gained through analysis of the 2017 data for the site allow some generic recommendations that may aid future planning of any survey work. These are presented below as 'operational and survey strategy' recommendations (Section 5.1) and 'analysis and interpretation' recommendations (Section 5.2) and fulfil the requirement for Objective 10 of this report.

5.1 Operational and survey strategy

- The Lundy SAC has been sampled during a number of targeted surveys (2007, 2012, 2017), however, the lack of consistency in station locations and sampling approaches significantly reduces the capacity of these data to inform a robust temporal assessment. We consider that the 2017 dataset represents a robust first data point (T0) on which future monitoring may be based. We therefore advocate that while the objectives of future surveys may differ, sampling designs should be developed following careful consideration of the sampling undertaken in 2017. As such, the outcomes of the 2017 survey should be reviewed during the planning stage of future surveys to ensure a robust temporal assessment of the condition of feature attributes can be conducted.
- Dedicated MBES data acquisition across the entire Lundy SAC, in association with ground truthing sediment samples and seabed imagery, would allow a full EUNIS habitat map to be produced across the entire SAC. Such a map would provide a sound basis from which any future changes in the extent and distribution of designated Annex I Sandbanks and Reefs may be monitored. However, the notable small-scale (within intensively sampled boxes) variability in sediments that have been demonstrated for Lundy will have implications for the confidence placed on any outputted map (Diesing *et al*., 2020). Furthermore, two sedimentary subfeatures are designated within the Lundy SAC ('A5.1 Sublittoral coarse sediment' and 'A5.2 Sublittoral sand'): a full habitat map encompassing the entire site would allow grab surveys of these habitats to be stratified to ensure sufficient sample numbers for meaningful assessment of any changes in condition. Finally, a habitat map based on full coverage acoustic data would aid delineation between 'A5.1 Sublittoral coarse sediment' (which is a designated feature) and 'A5.4 Sublittoral mixed sediments' (not a designated feature).
- While sufficient data were acquired for limited statistical analyses of the still images, the information obtained through the application of DDV approaches

was severely limited at Lundy by compromised video quality. The reason for this must be reviewed and if it transpires that seasonal (resulting from, for example, elevated primary production), tidal (e.g. spring tides) or meteorological (e.g. during or just after high winds) factors were likely responsible, then future surveys should avoid such circumstances and be conducted during times which may ensure the highest quality data are acquired. A great deal of the stills imagery was obscured by kelp fronds, highlighting the limitations of DDV methodology in kelp forests. In future surveys, and ROTV or towed array might be considered, which enables a maintenance of consistent altitude above the seabed (and thus the kelp fronds), allowing quantitative analysis of both still and video imagery.

- The Annex I stony reef assessment methodology undertaken for Lundy was limited by the lack of seabed video data, resulting in a lack of extent information as required by the method described by Irving (2009). Thus, the data were assessed using a lower resolution method (Duncan and Pinder, 2019). A more comprehensive methodology could have been implemented with more seabed video.
- Still images were acquired every 10 – 15 m along a transect, however it appears that the shutter release was operated to acquire the highest quality still image (i.e. when the camera was almost touching the seabed). While this methodology is very effective, it has a serious drawback in a kelp forest habitat as what constitutes a ‘Good or Excellent’ quality still excludes the kelp canopy and (due to the small FoV of still images) may not even include any kelp holdfasts. As such, relatively poor quality still images should not be excluded in the analysis of the stills images to ensure that kelp-dominated habitats are detected. To aid this, we propose that video data are captured which allow for each segment to have a “Kelp Presence/Absence” classification factor associated with each image. This would allow for the stills to be analysed as presented here while at the same time accounting for the presence of kelp.
- As many of the key epibiotic taxa are primarily seasonal (kelp and foliose red algae) it is recommended that future monitoring surveys are undertaken in the same season as that undertaken in 2017. While this endorsement equally pertains to monitoring infaunal assemblages, it is particularly crucial for monitoring where algal taxa are key assemblage components.
- Clearly, both the sediment PSA characteristics and infaunal assemblages within each of the three zones display large spatial variability. Future designs must decide how to address this to plan a survey with sufficient statistical power to detect any meaningful change. One way would be to compartmentalise each zone (particularly Zone 1 where the greatest spatial variability in infaunal assemblages and sediments were observed) into different areas or establish ‘sub-zones’. While the intensively sampled box

approach increases the statistical power to detect changes, assessing changes in the extent and distribution of designated features is better conducted *via* a single sample approach at a larger number of stations. In essence, this advocates a design more in line with that reported under Objective 3 where multiple replicates are sampled at specific stations. In addition, to enhance the spatial area of sampling, we would suggest that sampling a number of stations with single samples (i.e. commensurate with Objective 4) also be incorporated into the future design. While of limited use for a BACI design, these single sample stations would provide data over a wider spatial context and aid ground-truthing of any mapping approaches undertaken.

- In order to enhance the capacity of future sampling to detect the efficacy of the fisheries management zones on sustainably managing seabed assemblages, the choice of metric upon which to assess status, or indeed the selection of any indicator species, should be based on a sound consideration of the type of pressure on the bed. Not all fishing pressures affect the seabed in the same manner, most notably due to differences in gear types. While the types of gears used, where and when permitted at Lundy are known (see Section 4.3), the mechanism by which these gears interact with the various subfeatures should be considered to allow potential metrics to be postulated. Recent advances in our understanding in this respect from the peer-reviewed domain (e.g. Hiddink *et al*., 2017; Sciberras *et al*., 2018; Mazor *et al*., 2020) may offer such insights.

5.2 Analysis and interpretation

- Generally, there needs to be further development of robust indicators to assess changes in condition of Annex I features over time, both at the feature level and the site level (if appropriate). Once metrics that are to be used to assess the feature condition are agreed, a *post-hoc* power analysis should be undertaken on the infaunal data to aid planning of future sampling designs. While we have demonstrated that greater power to detect change (therefore less samples needed) is likely to be achieved through the adoption of the intensively sampled box approach, the restricted spatial extent of this approach should be borne in mind in terms of the capacity to meet the monitoring objectives.
- Infaunal biotopes assigned to each of the replicate grab samples within the intensively sampled boxes were generally consistent. While this demonstrates that taking replicate grab samples can be a useful way to determine the biotope of a region of sedimentary habitat, the overall use of biotopes may be limited to that of a descriptive tool, particularly at sites where little is known of the benthic habitat and the habitats are yet to be adequately characterised. The subjective nature of how biotopes are assigned from grabs, the varying

degree of information available to the analysts attributing them (e.g. associated biological or environmental information) and the ever-expanding number of biotopes, result in biotopes being of limited applicability as monitoring tools. The subjective nature of biotope classification is evident when reviewing the attribution of A5.611 (*Sabellaria spinulosa* on stable circalittoral mixed sediment). Stations where *S. spinulosa* was present were classified as one of three biotopes despite the similar abundances of this characterising taxa. Were this to occur over three different time periods rather than at three different sites, there is the possibility of erroneously determining large scale changes in the biotope present at a site.

- Epifaunal assemblage analysis has most often been undertaken using multivariate statistical routines, as made available within the Primer software package. These routines have been designed and tested using infaunal abundance data (i.e. those pertaining to infaunal data from grabs and corers). Conversely, the 'vegan' package, written in the statistical language R, contains multivariate tests and standardisation routines which have been specifically developed to analyse ground cover communities (i.e. terrestrial vegetation analyses) in a quantitative manner. In the present report, we demonstrate the use of the permutationally driven indicator metric 'IndVal' in providing information into which taxa best characterise observed assemblages and suggest that this approach be further investigated. Further direct comparisons between traditional Primer-based methods of epifaunal analysis and the use of the indicator species "IndVal" metric should be undertaken to assess for the differences between the two approaches on an "ideal" imagery dataset.
- To improve the information gained through the contaminants assessment and provide a greater understanding of any temporal changes, identification of the sources of PAHs could be undertaken. Analysis of speciated PAH lists (parents and alkyl derivatives) should be undertaken to assess the source assignment to give a better picture of the influences. Given the relative coastal location of the Lundy SAC, there is likely to be a significant input of pyrolytic PAHs from mainland sources, although the elevated volatiles suggest some chronic petrogenic inputs.

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7 Appendix 1. Rationale behind the revision to the original reporting objectives (© Natural England and Cefas 2022)

Original Reporting Objective	Reporting Objective	Rationale for change to Objective
1. Provide a description of the **extent**, **distribution and structural** attributes, and the **supporting processes**, of the designated features within the site, to enable subsequent condition monitoring and assessment	1. Objective unaltered	Reporting objective unaltered. Description of extent, distribution, structural and functional attributes of hard substrata habitats limited due to limited quality (largely resulting from limited water clarity) of video footage.
2. Conduct a temporal comparison of infaunal communities, biotopes, particle size distribution and contaminant levels between 2007, 2012 & 2017 data (wider dataset)	2. Conduct a temporal comparison of contaminant levels between 2007, 2012 & 2017.	2007 and 2017 data not comparable for infauna due to the use of a 0.04 m^2 Van Veen grab in 2007, precludes even a qualitative comparison. Only four stations are comparable between 2012 and 2017 for infauna, this is insufficient for any meaningful assessment. Gear type differences deemed acceptable for temporal comparison of contaminants.
3. Conduct a spatial and temporal comparison of intensely sampled boxes within different fisheries management zones (infaunal communities, biotopes, particle size distribution and contaminant levels) between 2007, 2012 & 2017 data, with particular reference to the squid fishery	3. Conduct a spatial comparison of intensely sampled boxes within different fisheries management zones (infaunal communities, particle size distribution)	Data do not allow temporal comparison for infauna (see above). Infaunal data from a small suite of samples (replicates in an intensively sampled box in this case) are not considered appropriate for the derivation of biotopes. Biotopes based on grab data should only be conducted when based on multivariate assessment of a large number of samples and the presence of distinct assemblages, each with particular discriminating (or

Original Reporting Objective	Reporting Objective	Rationale for change to Objective
		dominant) species can be associated with their corresponding sediment types. The squid fishery management zone has been removed (see methods section for rationale) from the survey design and samples collected within this region are analysed as those belonging to fisheries management Zone 1 (general use zone). Removal of reference to contaminant levels as these were not sampled in intensively sampled boxes.
4. Evaluate natural variability within the No Take Zone, in comparison to other fisheries management areas	4. Evaluate wider spatial variability (infauna, particle size) within and across fisheries management areas	The spatial data from all three fisheries management zones will be compared. Single station samples across the four fisheries management areas used to evaluate spatial variability at wider spatial scales than Objective 3.
5. Evaluate the efficacy of the 100 m intensively sampled boxes as a method by which to assess the effectiveness of management measures over time	5. Comparison of spatial variability (infauna, particle size distribution) between intensively sampled boxes approach with that from wider sampling	The absence of any suitable temporal data precludes an assessment of the effectiveness of any management measures. The 2017 data will be used to compare observed spatial variability using the wider, single sample spatial approach (data analysed in reporting Objective 4) with that based on the intensively sampled boxes (data analysed in reporting Objective 3). This will be undertaken by comparing the coefficients of variability of a suite of univariate metrics of community structure. Due to the current absence of agreed metrics, a power analysis not to be conducted.
6. Update the existing habitat map with new acoustic and groundtruthing data	6. Produce geomorphological and sediment map for region	Not possible to update existing habitat map due to lack of overlapping sampling stations.

Original Reporting Objective	Reporting Objective	Rationale for change to Objective
	of SAC where acoustic data exist	Temporal difference in acquisition of acoustic (2015) and groundtruth (2012 and 2017) data limits confidence in sediment map produced. Acoustic data only available for small region of SAC.
7. Compare the abundance and distribution of NIS between 2007, 2012 and 2017	7. Objective unaltered	Gear type differences between years (especially in 2007) will need to be caveated in interpretation of temporal differences.
8. Note observations of any Habitat or Species FOCI not covered by Designation Order as features of the site	8. Objective unaltered	N/A
9. Present evidence relating to marine litter (Descriptor 10), to satisfy requirements of the Marine Strategy Framework Directive	9. Objective unaltered	N/A
10. Provide practical recommendations for appropriate future monitoring approaches for both the designated features and their natural supporting processes (e.g. metric selection, survey design, data collection approaches) with a discussion of their requirements	10. Objective unaltered	N/A

Appendix 2. Acoustic data treatment

A multiresolution segmentation at SP10, S0 and C0.3 was firstly adopted, using only BPI40-50 (weight 2) and BPI5-10 (weight 1) to delineate the topography. A general class **Features** was defined using BPI (anything with BPI10-20 > 3, and then any object with relative border to **Features** > 0.1 and BPI40-50 > 0 (looped through infinitely) to isolate topographically distinguishable features from the rest of the seabed. This included parts of the sandbank, the sandwaves and the most prominent bedrock outcrops. **Bedrock** was then partly isolated from **Features** using Mean slope > 5°. The **Sandbank** was partly isolated from unclassified objects using Mean Standard Height > -23 and Std. Dev. Slope > 1.4, then extended including **Features** and **Bedrock** with mean Std. Height > -29 and relative border to **Sandbank** > 0.1. The **Shipwreck** and **Incision** classes were classified manually at this stage. This partly mapped the above classes.

The unclassified objects were remerged and re-segmented at SP10, S0 and C0.3 but this time looking for the finer details using BPI5-10 (weight 1) and slope (weight 0.2). The presence of artefacts on the MBES data hindered the isolation of the smaller features on the seabed. **Rippled sediment** was classified taking advantage of the high backscatter (unclassified with Mean backscatter > -23.7 and Mean slope > 2 and Mean slope < 3.8). Since this class included parts of unclassified bedrock, the **Bedrock** class was refined adding any **Features** or **Rippled sediment** object within ~40 m of the classified bedrock. This operation was possible because of the spatial separation between the real ripple fields in the north and the bedrock in the south.

A multiple object difference conditions-based fusion algorithm was then applied to reduce the number of objects and classify the flat area of the sandbank (Merge adjacent (0.1 contact) objects with maximum difference in Mean backscatter of 1 and standard deviation BPI40-50 of 0.1). Then an infinite loop was applied to classify **Features** and unclassified objects with Mean BPI40-50 > -0.2 and Mean BPI40-50 < 1.3 and Rel. border to Sandbank > 0.1 as **Sandbank**. Since some ripples are present on the sandbank, the **Sandbank** objects were fused in a single object and re-segmented with SP10, S0 and C0.3 using BPI10-20 (weight 1) and BPI5-10 (weight 0.5) and Std. Height (weight 0.2). Thus, any created **Sandbank** object with aspect > 88 or < 100 and standard deviation slope > 1.1 was classified as **Rippled sediment**.

The remaining **Features** were reclassified as **sandwaves and hummocky seabed** while the rest of the unclassified as 'Irregular seabed'. The noise of the MBES and backscatter signal and the subtle differences between different seabed features imposed a final manual intervention to adjust the classification and clean the final product.

Appendix 3. Infauna data truncation protocol

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

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

Details of the data preparation and truncation protocols applied to the infaunal datasets acquired at Lundy SAC ahead of the analyses reported here are provided below, and a list of taxa removed through this process is presented in Table 24.

- Taxa are often assigned as 'juveniles' during the identification stage with little evidence for their actual reproductive natural history (except for some well-studied molluscs and commercial species). Many truncation methods involve the removal of all taxa with the 'juvenile' qualifier. However, a decision must be made on whether removal of all 'juveniles' from the dataset is appropriate or whether they should be combined with the 'adults' of the same species, where present. For the infaunal data collected at the Lundy SAC: where a species level identification was labelled 'juvenile' the record was combined with the associated species level identification, when present, or the 'juvenile' label was removed when no adults of the same species had been recorded.
- Meiofauna (i.e. nematodes), vertebrate species (i.e. fish), records of animals in larval or reproductive stages (e.g. crustacean larvae) and plants were removed.

Table 24. Taxa removed from the Lundy SAC 2017 dataset before infaunal analysis (© Natural England and Cefas 2022).

Taxon	Qualifier	Kingdom	Phylum	Class
Animalia	N/A	Animalia	Animalia	Animalia
Astrorhiza	N/A	Chromista	Foraminifera	Monothalamea
Nematoda	N/A	Animalia	Nematoda	Nematoda
Eusyllis	Epitoke	Animalia	Annelida	Polychaeta
Exogone naidina	Epitoke	Animalia	Annelida	Polychaeta
Sphaerosyllis	Epitoke	Animalia	Annelida	Polychaeta
Prosphaerosyllis	Epitoke	Animalia	Annelida	Polychaeta
Acari	N/A	Animalia	Arthropoda	Arachnida
Thoracica	N/A	Animalia	Arthropoda	Hexanauplia
Copepoda	N/A	Animalia	Arthropoda	Hexanauplia
Myodocopida	N/A	Animalia	Arthropoda	Ostracoda
Mysidae	N/A	Animalia	Arthropoda	Malacostraca
Heteromysis	N/A	Animalia	Arthropoda	Malacostraca
Gnathiidae	Larva	Animalia	Arthropoda	Malacostraca
Decapoda	Megalopa	Animalia	Arthropoda	Malacostraca
Decapoda	Zoea	Animalia	Arthropoda	Malacostraca
Pisidia longicornis	Megalopa	Animalia	Arthropoda	Malacostraca
Mollusca	N/A	Animalia	Mollusca	Mollusca
Branchiostoma	N/A	Animalia	Chordata	Leptocardii
Actinopterygii	Eggs	Animalia	Chordata	Actinopterygii
Ammodytes	N/A	Animalia	Chordata	Actinopterygii

Appendix 4. Epifauna data truncation protocol applied to seabed imagery data (© Natural England and Cefas 2022)

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
U_Faunal_turf	1. percentage cover	Merge	Faunal Turf
U_Faunal_turf	1. percentage cover		
U. red algae_foliose	1. percentage cover	Keep	Foliose red algae
U. red algae_filamentous	1. percentage cover	Keep	Filamentous red algae
U. red algae_foliose	1. percentage cover	Remove	N/A
Corallinaceae	1. percentage cover	Keep	Corallinaceae
Calliblepharis ciliata	1. percentage cover	Keep	*Calliblepharis ciliata*
Dilsea carnosa	1. percentage cover	Keep	*Dilsea carnosa*
Chondrus crispus	1. percentage cover	Keep	*Chondrus crispus*
Delesseria sanguinea	1. percentage cover	Keep	*Delesseria sanguinea*
Phycodrys rubens	1. percentage cover	Keep	*Phycodrys rubens*
U. brown algae_foliose	1. percentage cover	Keep	Foliose brown algae
U. brown algae_filamentous	1. percentage cover	Keep	Filamentous brown algae
Dictyopteris polypodioides	1. percentage cover	Keep	Dictyopteris polypodioides
Dictyota dichotoma	1. percentage cover	Keep	*Dictyota dichotoma*
Desmarestia ligulata	1. percentage cover	Keep	*Desmarestia ligulata*

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Laminaria	1. percentage cover	**Merge**	*Laminaria* spp.
Laminaria hyperborea	1. percentage cover		
Halidrys siliquosa	1. percentage cover	**Keep**	*Halidrys siliquosa*
Porifera	0. count	**Remove**	N/A
Porifera	1. percentage cover	**Keep**	Porifera_Encrustung (Indet.)
Porifera	0. count	**Remove**	N/A
Porifera	1. percentage cover	**Keep**	Porifera_Massive (Indet.)
Porifera	1. percentage cover	**Keep**	Porifera_Papilate (Indet.)
Porifera	1. percentage cover	**Keep**	Porifera_Repent (Indet.)
Leucosolenia	1. percentage cover	**Keep**	*Leucosolenia*
Sycon ciliatum	0. count	**Remove**	N/A
Pachymatisma johnstonia	1. percentage cover	**Keep**	*Pachymatisma johnstonia*
Tethya	0. count	**Remove**	N/A
Polymastia boletiformis	0. count	**Remove**	N/A
Polymastia penicillus	1. percentage cover	**Keep**	*Polymastia penicillus*
Cliona celata	1. percentage cover	**Keep**	*Cliona celata*_Boring
Cliona celata	1. percentage cover	**Keep**	*Cliona celata*_Encrusting
Halichondria (Halichondria) panicea	1. percentage cover	**Keep**	*Halichondria (Halichondria) panicea*
Amphilectus fucorum	1. percentage cover	**Keep**	*Amphilectus fucorum*_Repent

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Amphilectus fucorum	1. percentage cover	**Keep**	*Amphilectus fucorum*_Encrusting
Hymedesmia (Hymedesmia) paupertas	1. percentage cover	**Keep**	*Hymedesmia (Hymedesmia) paupertas*
Hemimycale columella	1. percentage cover	**Keep**	*Hemimycale columella*
Raspailia (Clathriodendron) hispida	0. count	**Remove**	N/A
Raspailia (Raspailia) ramosa	0. count	**Remove**	N/A
Haliclona (Rhizoniera) viscosa	1. percentage cover	**Keep**	*Haliclona (Rhizoniera) viscosa*
Dysidea fragilis	1. percentage cover	**Keep**	*Dysidea fragilis*
Aurelia aurita	presence	**Remove**	N/A
Hydrozoa	1. percentage cover	**Keep**	Hydrozoa
Tubularia indivisa	1. percentage cover	**Keep**	*Tubularia indivisa* (Live)
Tubularia indivisa	1. percentage cover	**Keep**	*Tubularia indivisa* (Tubes)
Haleciidae	1. percentage cover	**Keep**	Haleciidae
Sertulariidae	1. percentage cover	**Keep**	Sertulariidae
Hydrallmania falcata	1. percentage cover	**Keep**	*Hydrallmania falcata*
Plumularioidea	1. percentage cover	**Keep**	Plumularioidea
Nemertesia	1. percentage cover	**Merge**	*Nemertesia* spp.
Nemertesia antennina	1. percentage cover		
Nemertesia ramosa	1. percentage cover		

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Aglaopheniidae	1. percentage cover	**Keep**	Aglaopheniidae
Alcyonium digitatum	1. percentage cover	**Keep**	*Alcyonium digitatum*
Zoantharia	1. percentage cover	**Keep**	*Zoantharia*
Actiniaria	0. count	**Remove**	N/A
Anemonia viridis	0. count	**Remove**	N/A
Urticina felina	0. count	**Remove**	N/A
Sagartiidae	0. count	**Remove**	N/A
Actinothoe sphyrodeta	0. count	**Remove**	N/A
Corynactis viridis	1. percentage cover	**Keep**	*Corynactis viridis*
Caryophyllia (Caryophyllia) smithii	0. count	**Remove**	N/A
Prostheceraeus vittatus	0. count	**Remove**	N/A
Bispira volutacornis	0. count	**Remove**	N/A
Serpulidae	1. percentage cover	**Keep**	Serpulidae
Thoracica	1. percentage cover	**Keep**	Thoracica
Decapoda	0. count	**Remove (Too Broad)**	N/A
Caridea	0. count	**Remove**	N/A
Paguridae	0. count	**Remove**	N/A
Brachyura	0. count	**Remove**	N/A
Ebalia	0. count	**Remove**	N/A
Maja squinado	0. count	**Remove**	N/A
Inachus	0. count	**Remove**	N/A
Macropodia	0. count	**Remove**	N/A
Portunidae	0. count	**Remove**	N/A
Necora puber	0. count	**Remove**	N/A

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Gastropoda	0. count	**Remove**	N/A
Gibbula	0. count	**Remove**	N/A
Calliostoma zizyphinum	0. count	**Remove**	N/A
Nudibranchia	0. count	**Remove**	N/A
Nudibranchia	0. count	**Remove**	N/A
Nudibranchia	0. count	**Remove**	N/A
Nudibranchia	0. count	**Remove**	N/A
Edmundsella pedata	0. count	**Remove**	N/A
Pecten maximus	0. count	**Remove**	N/A
Brachiopoda	0. count	**Remove**	N/A
Bryozoa	1. percentage cover	**Keep**	Bryozoa_Encrusting (Indet.)
Bryozoa	1. percentage cover	**Remove (Too Broad)**	N/A
Bryozoa	1. percentage cover	**Keep**	Bryozoa_Turf (Indet.)
Crisiidae	1. percentage cover	**Keep**	Crisiidae
Alcyonidium diaphanum	1. percentage cover	**Keep**	*Alcyonidium diaphanum*
Membranipora membranacea	1. percentage cover	**Keep**	*Membranipora membranacea*
Electra pilosa	1. percentage cover	**Keep**	*Electra pilosa*
Flustridae	1. percentage cover	**Merge**	Flustridae
Flustra foliacea	1. percentage cover		
Buguloidea	1. percentage cover	**Keep**	Buguloidea
Crisularia plumosa	1. percentage cover	**Keep**	*Crisularia plumosa*
Caberea boryi	1. percentage cover	**Keep**	*Caberea boryi*

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Cellaria	1. percentage cover	**Keep**	*Cellaria*
Reptadeonella violacea	1. percentage cover	**Keep**	*Reptadeonella violacea*
Pentapora foliacea	1. percentage cover	**Keep**	*Pentapora foliacea*
Parasmittina trispinosa	1. percentage cover	**Keep**	*Parasmittina trispinosa*
Cellepora pumicosa	1. percentage cover	**Keep**	*Cellepora pumicosa*
Asteroidea	0. count	**Remove**	N/A
Henricia	0. count	**Remove**	N/A
Marthasterias glacialis	0. count	**Remove**	N/A
Ophiuroidea	0. count	**Remove**	N/A
Ophiura albida	0. count	**Remove**	N/A
Echinus esculentus	0. count	**Remove**	N/A
Holothuria (Panningothuria) forskali	0. count	**Remove**	N/A
Dendrochirotida	0. count	**Remove**	N/A
Ascidiacea	1. percentage cover	**Merge**	Ascidiacea
Ascidiacea	1. percentage cover		
Ascidiacea	0. count	**Remove**	N/A
Clavelina lepadiformis	1. percentage cover	**Keep**	*Clavelina lepadiformis*
Polyclinidae	1. percentage cover	**Keep**	Polyclinidae
Polyclinidae	1. percentage cover	**Keep**	Polyclinidae
Didemnidae	1. percentage cover	**Keep**	Didemnidae
Stolonica socialis	1. percentage cover	**Keep**	*Stolonica socialis*

Original Entry	Method used for estimation of abundance	Truncation Action	Percentage Cover- Final Entry
Scyliorhinus canicula	0. count	**Remove (Highly Mobile)**	N/A
Actinopterygii	0. count	**Remove (Highly Mobile)**	N/A
Conger conger	0. count	**Remove (Highly Mobile)**	N/A
Gadidae	0. count	**Remove (Highly Mobile)**	N/A
Pholis gunnellus	0. count	**Remove (Highly Mobile)**	N/A
Scophthalmidae	0. count	**Remove (Highly Mobile)**	N/A
Egg mass indet	presence	**Remove**	N/A
Egg case	presence	**Remove**	N/A

Appendix 5. Objective 1: Univariate metrics of community structure of the four sedimentary BSHs sampled across the Lundy SAC in 2017

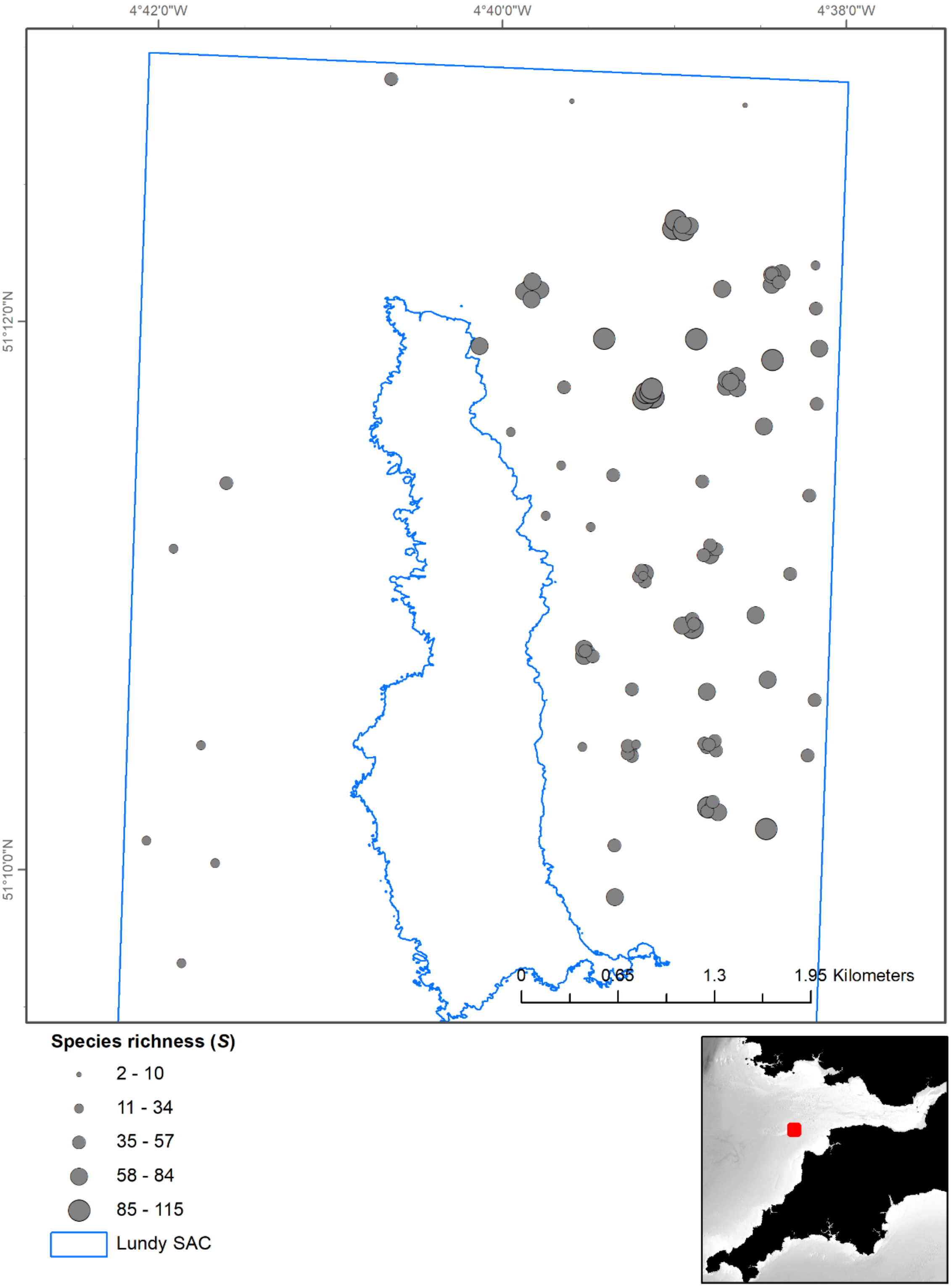

Figure 38. Spatial distribution of species richness (number of taxa) of infaunal taxa collected at Lundy SAC in 2017 using the mini Hamon grab (© Natural England and Cefas 2022).

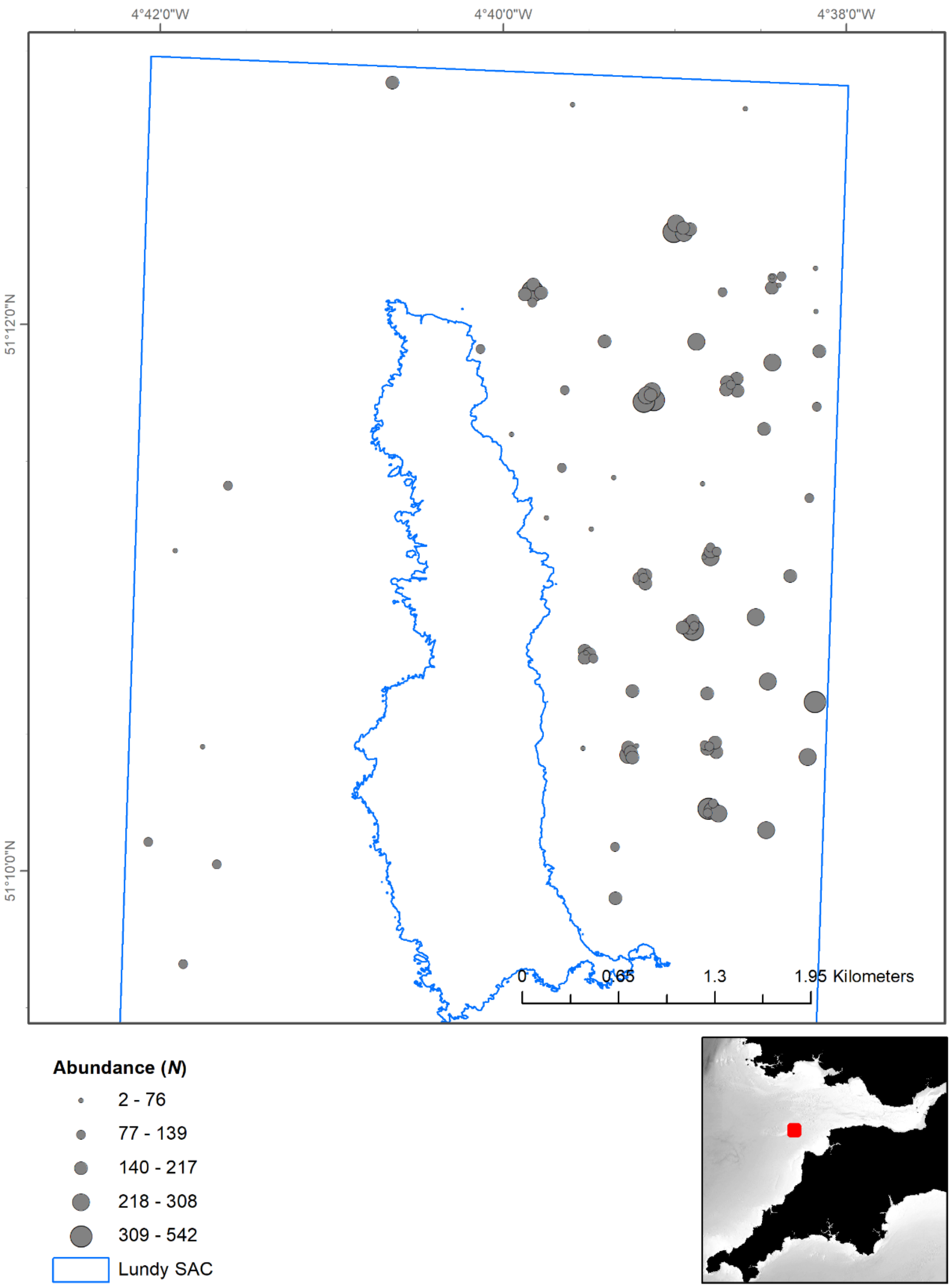

Figure 39. Spatial distribution of total abundance (number of individuals) of infaunal taxa collected at Lundy SAC in 2017 using the mini Hamon grab (© Natural England and Cefas 2022).

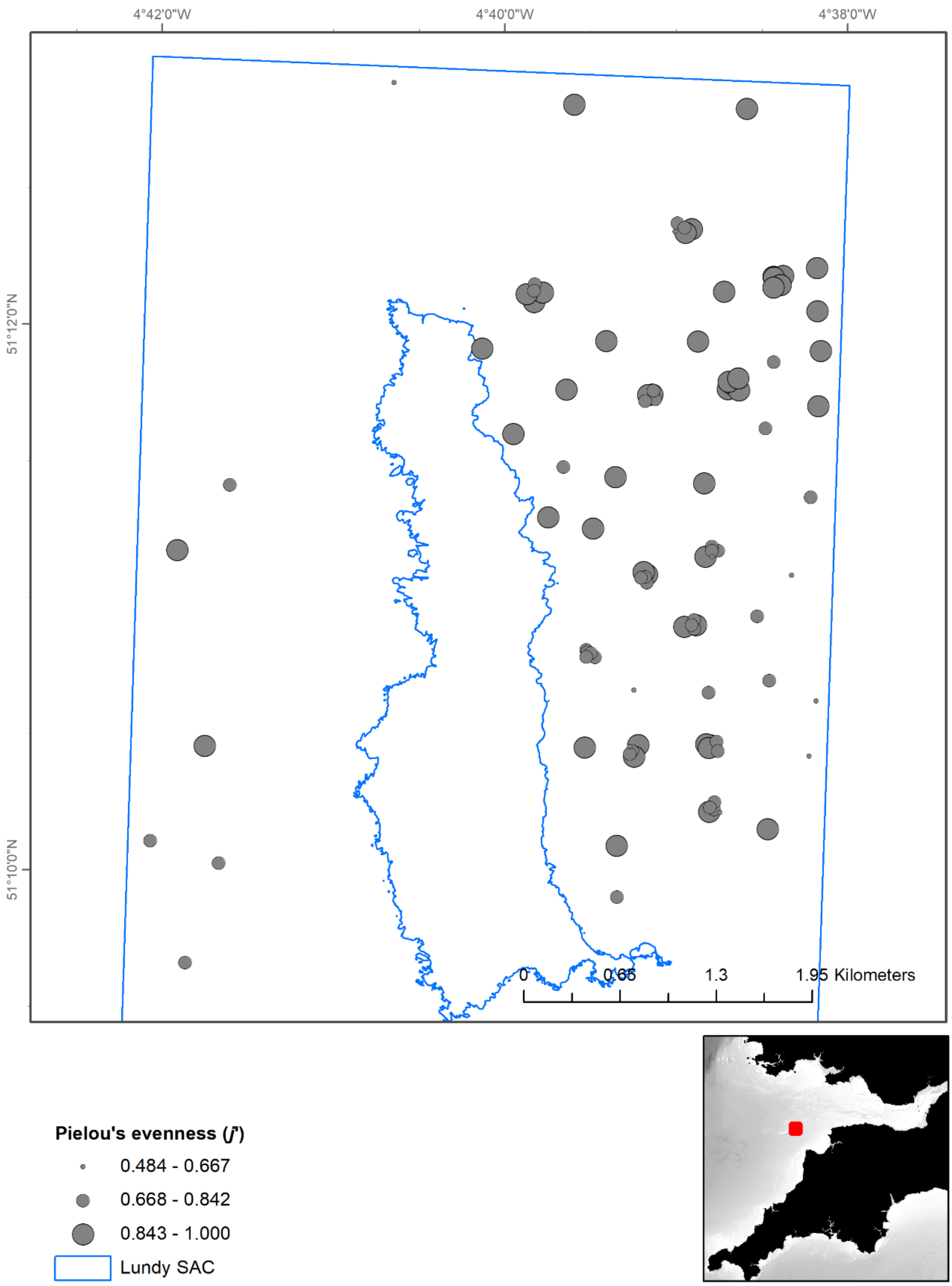

Figure 40.Spatial distribution of species evenness (Pielou's measure) of infaunal taxa collected at Lundy SAC in 2017 using the mini Hamon grab (© Natural England and Cefas 2022).

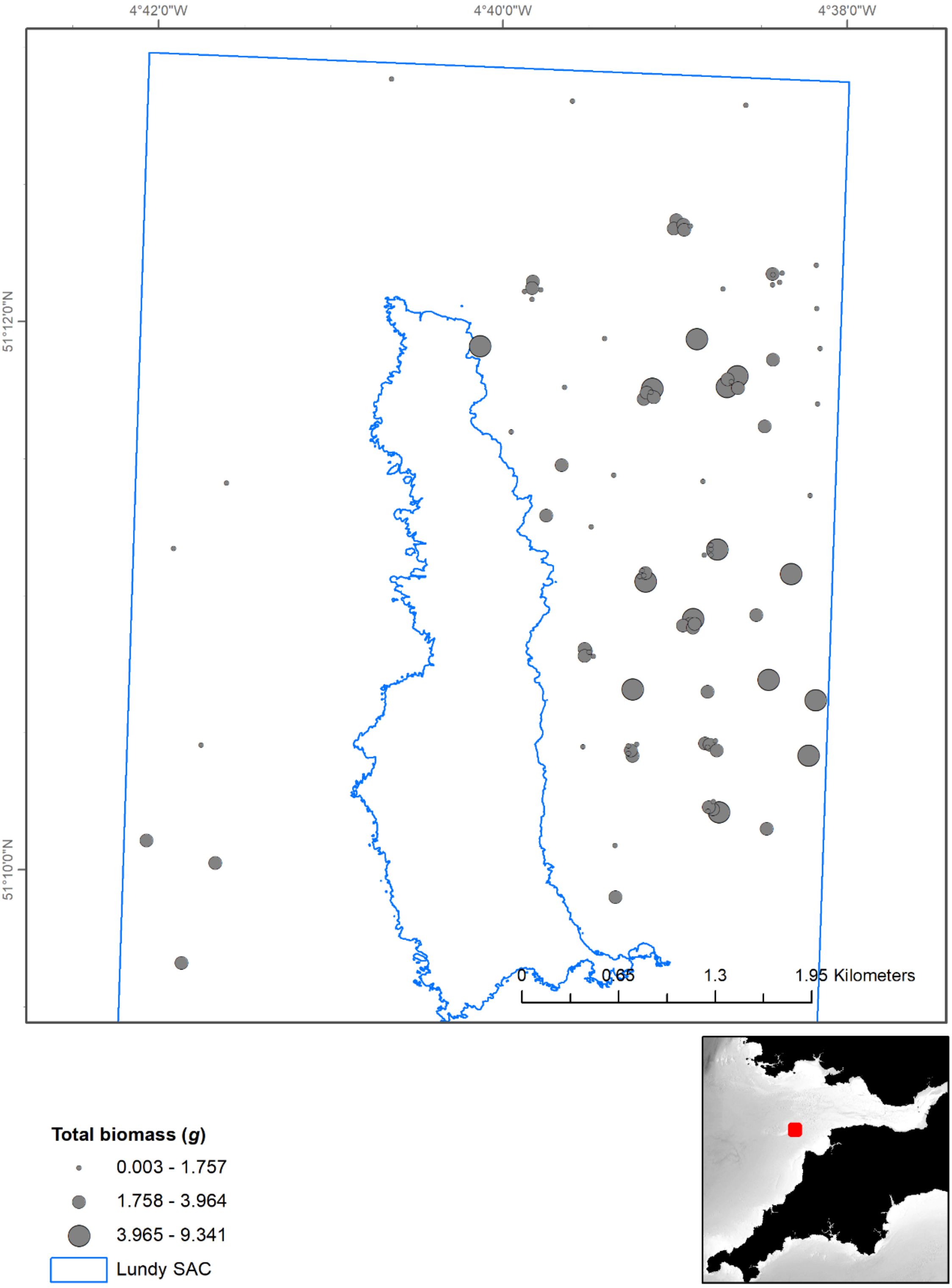

Figure 41. Spatial distribution of total biomass (wet weight in *g*) of infaunal taxa collected at Lundy SAC in 2017 using the mini Hamon grab (© Natural England and Cefas 2022).

Table 25. Descriptive statistics of the univariate metrics of infaunal community structure by EUNIS habitat class (© Natural England and Cefas 2022).

EUNIS habitat	Statistic	Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
A5.1 Sublittoral coarse sediment (n = 41)	Min.	30.0	41.0	0.5	0.1
	1stQu.	55.0	120.0	0.8	0.8
	Median	74.0	181.0	0.9	1.9
	Mean	73.9	195.0	0.8	2.4
	3rdQu.	89.0	240.0	0.9	3.5
	Max.	115.0	542.0	1.0	9.3
	St. dev	22.0	107.0	0.1	1.9
A5.2 Sublittoral sand (n = 15)	Min.	2.0	2.0	0.7	0.0
	1stQu.	24.5	59.0	0.8	0.6
	Median	37.0	115.0	0.8	1.2
	Mean	35.7	115.2	0.8	1.8
	3rdQu.	51.5	157.5	0.9	2.2
	Max.	67.0	260.0	1.0	6.6
	St. dev	20.7	84.5	0.1	1.9
A5.3 Sublittoral mud (n = 8)	Min.	18.0	28.0	0.8	0.7
	1stQu.	36.5	76.0	0.8	1.2
	Median	44.0	96.5	0.9	2.2
	Mean	41.9	104.9	0.9	2.3
	3rdQu.	50.0	134.0	0.9	3.3
	Max.	59.0	194.0	1.0	4.3
	St. dev	12.6	52.7	0.1	1.3
A5.4 Sublittoral mixed sediment (n = 34)	Min.	14.0	26.0	0.5	0.4
	1stQu.	43.0	105.8	0.8	1.5
	Median	50.5	161.5	0.8	2.2
	Mean	51.6	173.7	0.8	2.5
	3rdQu.	62.0	202.8	0.9	3.0
	Max.	87.0	491.0	0.9	7.8
	St. dev	16.3	101.0	0.1	1.6

Appendix 6. Objective 2: Maps of sediment physico-chemical properties and contaminants concentrations

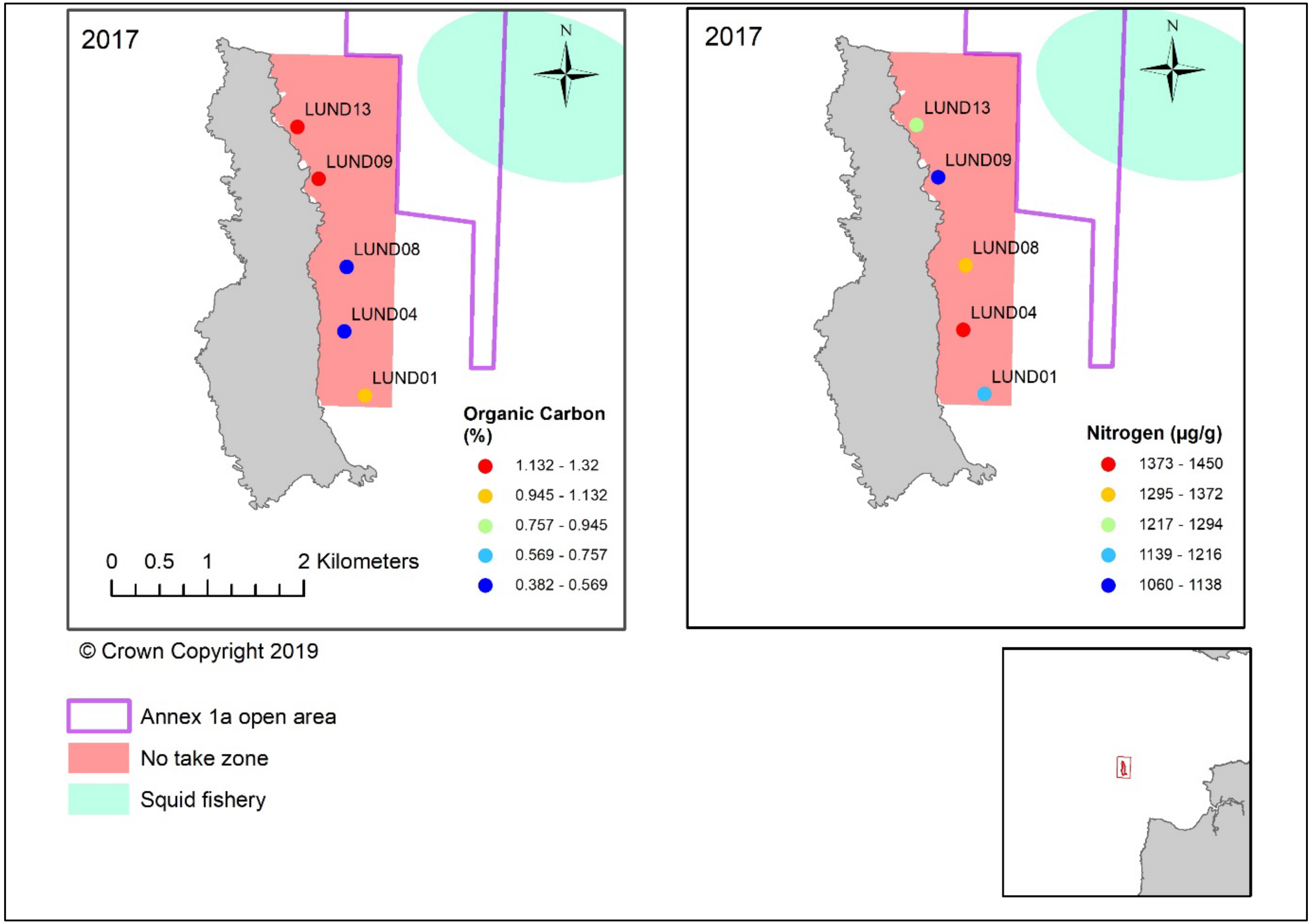

Figure 42. Sediment organic carbon and nitrogen content at Lundy SAC, 2017 (© Natural England and Cefas 2022).

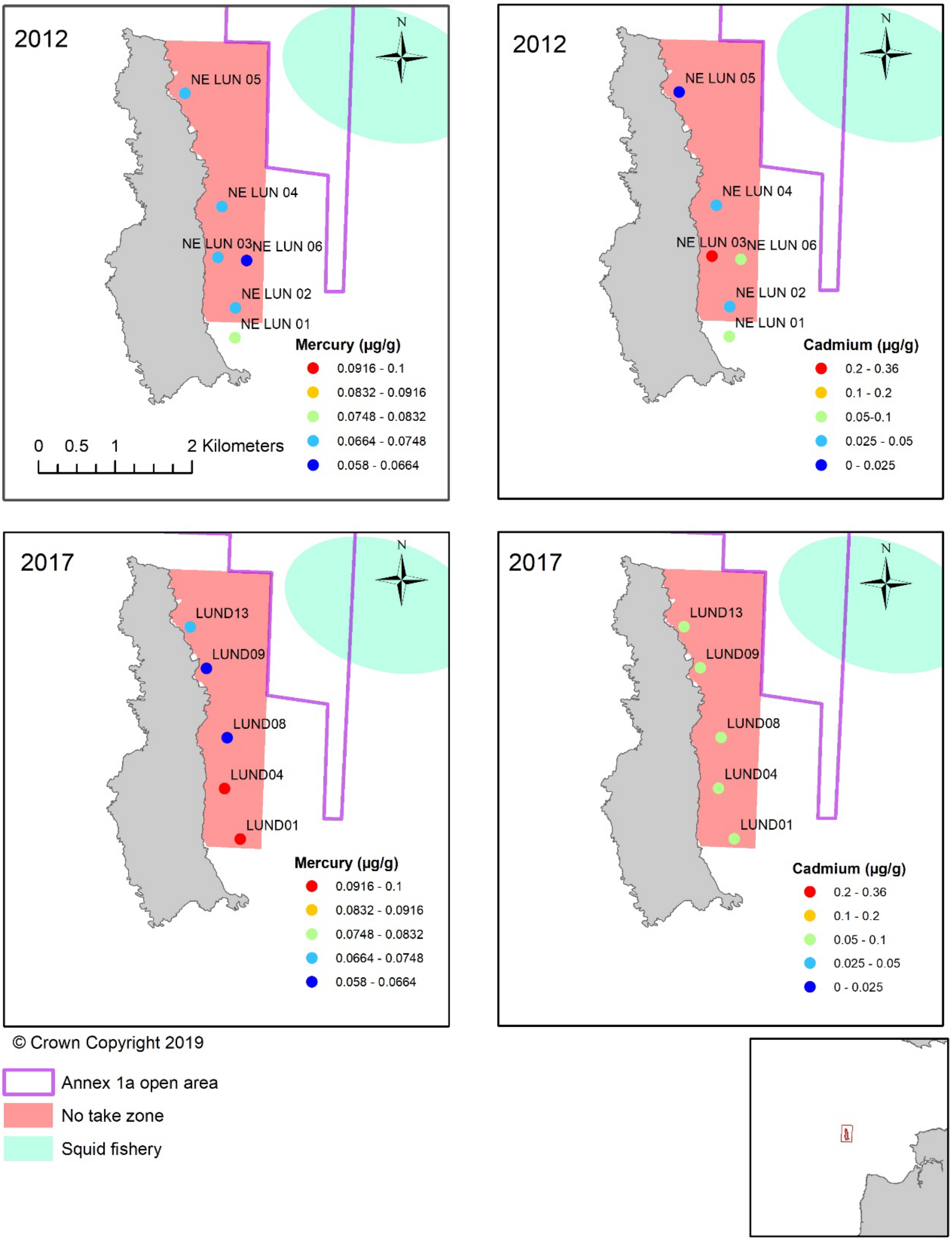

Figure 43. Sediment Mercury (Hg) and Cadmium (Cd) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

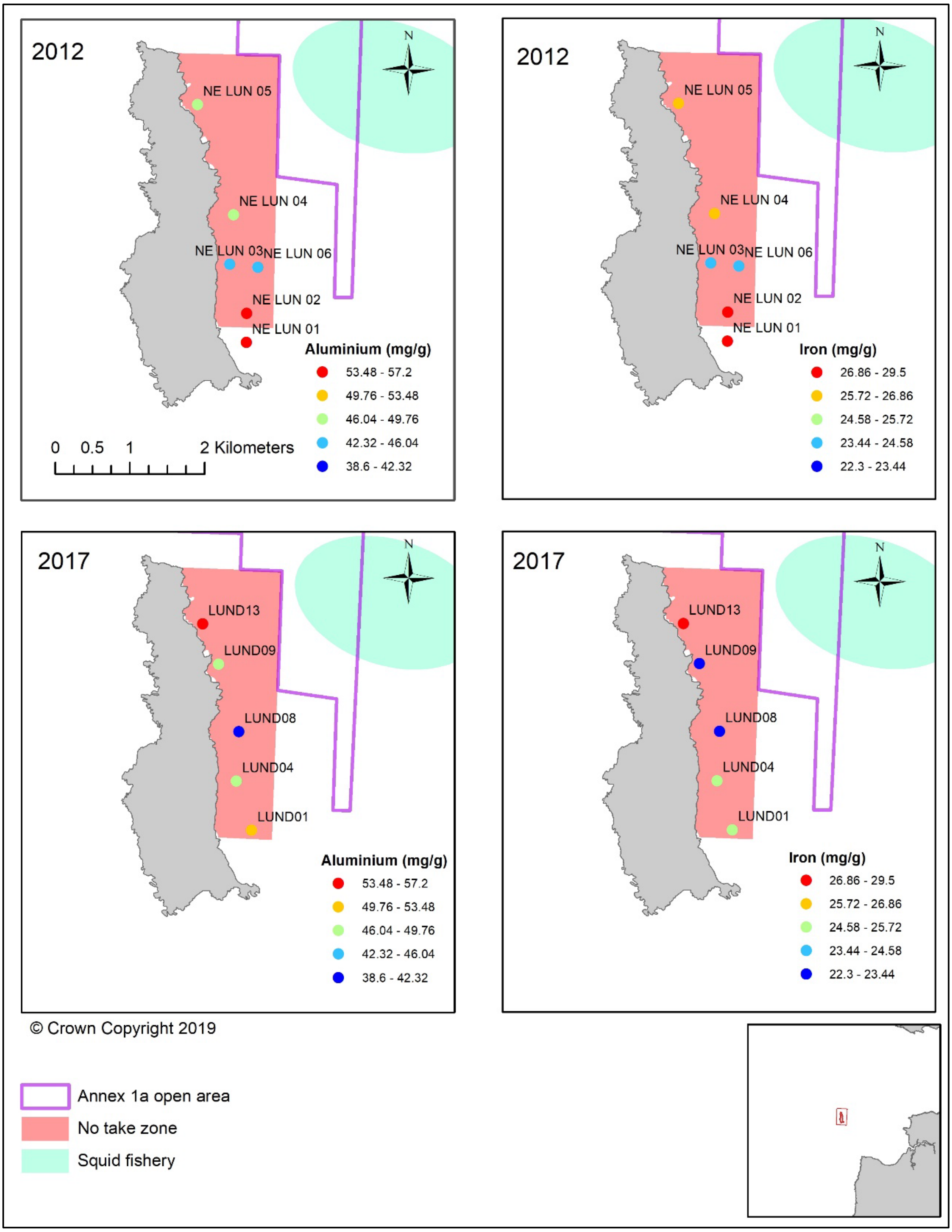

Figure 44. Sediment Aluminium (Al) and Iron (Fe) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

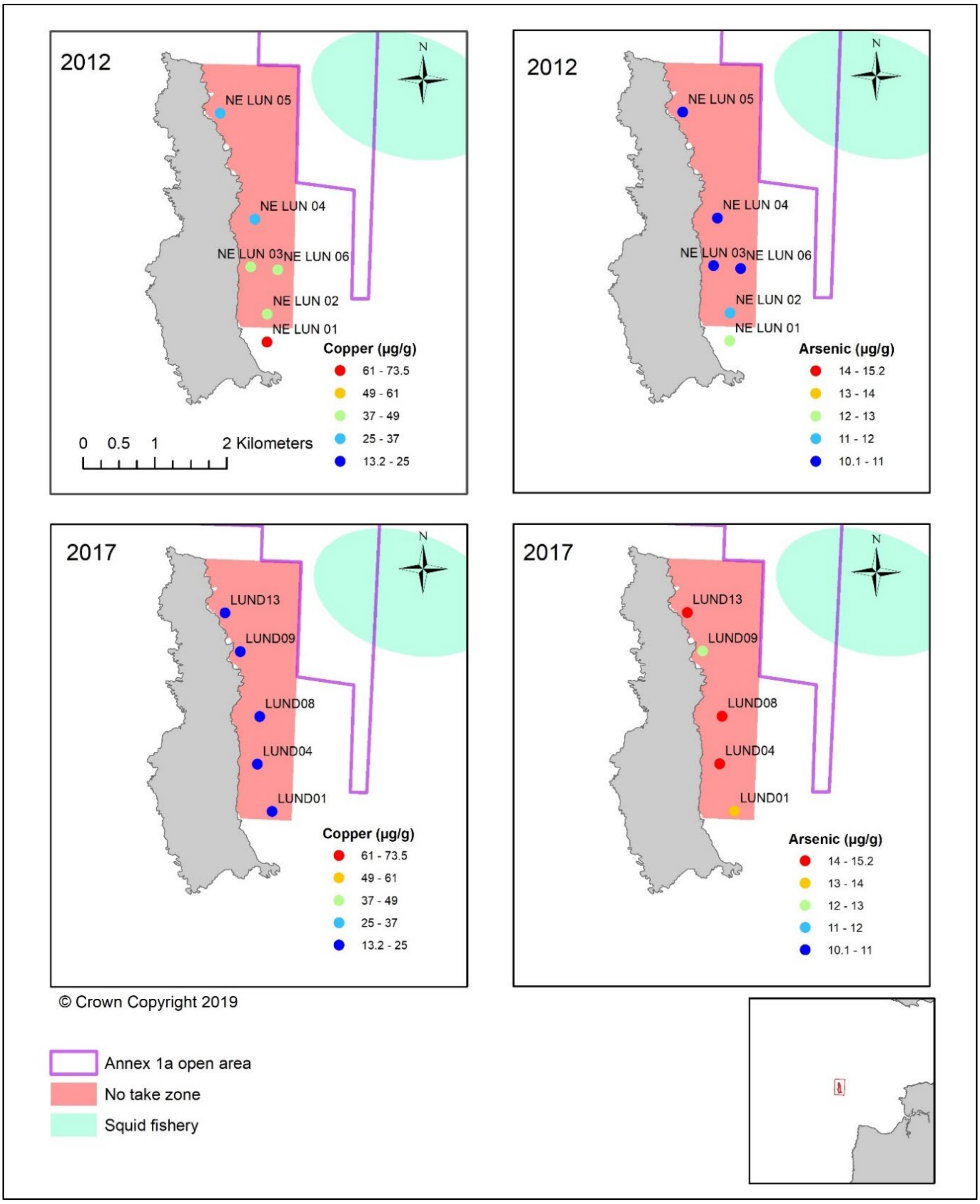

Figure 45. Sediment Copper (Cu) and Arsenic (As) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

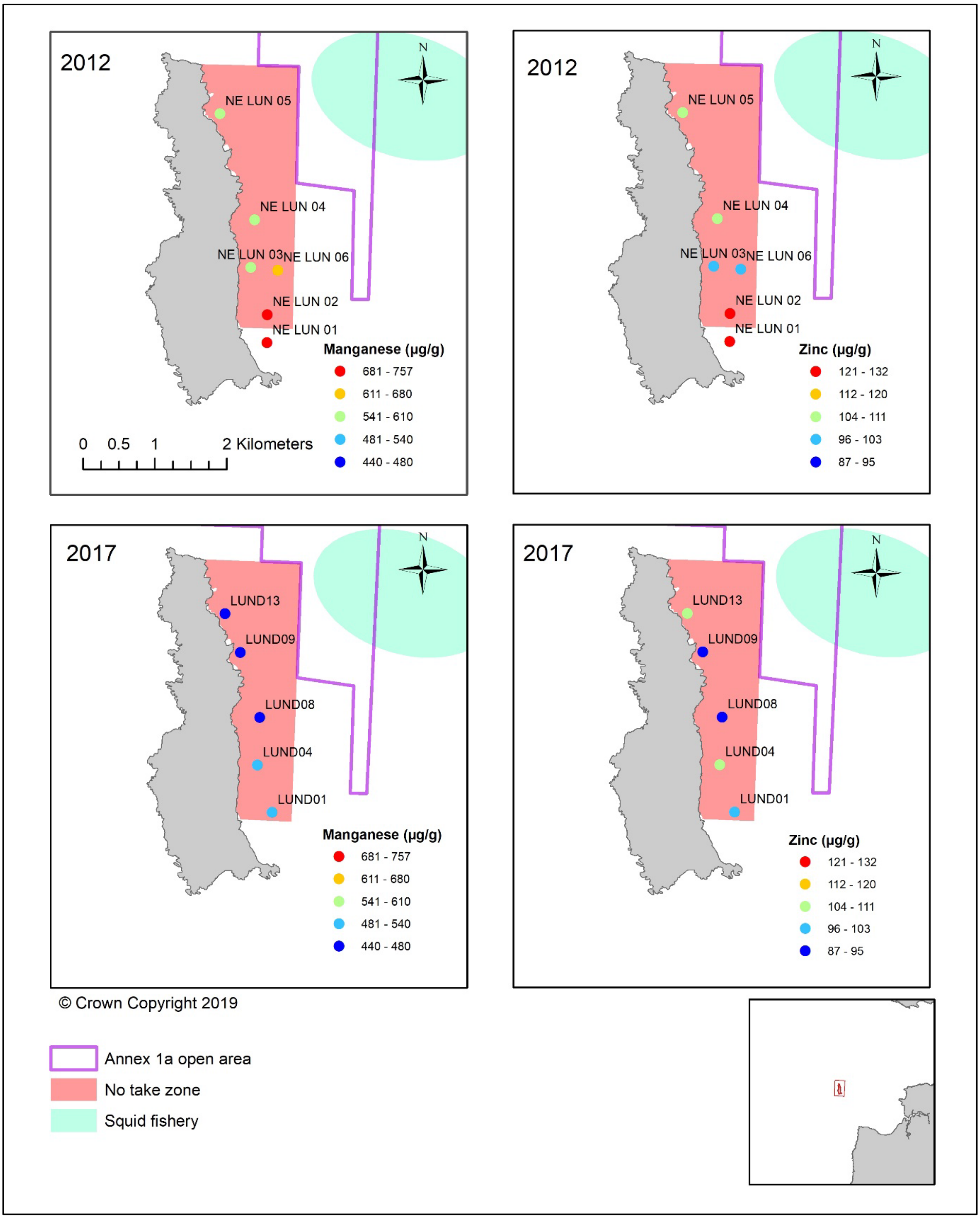

Figure 46. Sediment Manganese (Mn) and Zinc (Zn) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

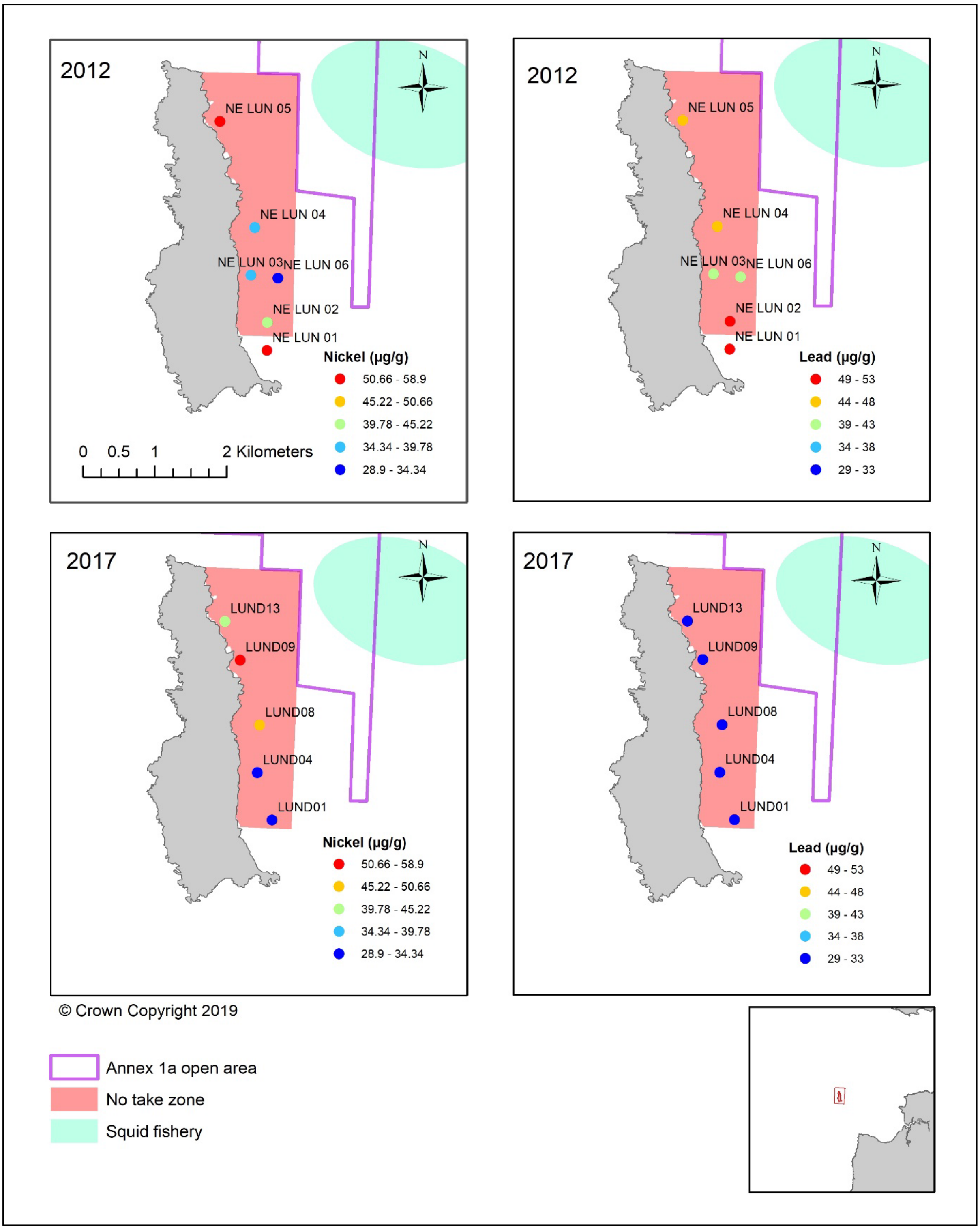

Figure 47. Sediment Nickel (Ni) and Lead (Pb) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

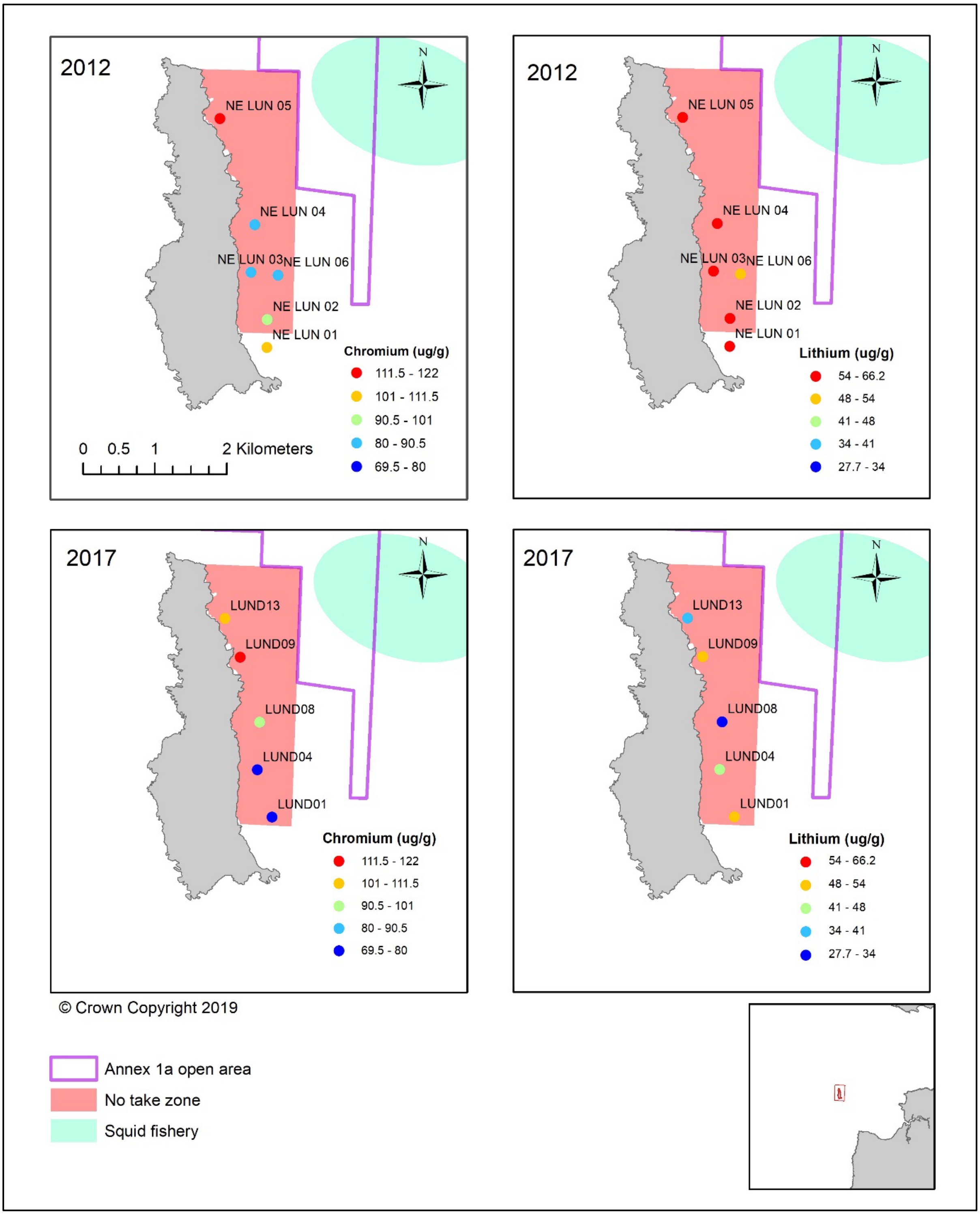

Figure 48. Sediment Chromium (Cr) and Lithium (Li) content (Dry Wt) at Lundy SAC in 2017 and 2012 (© Natural England and Cefas 2022).

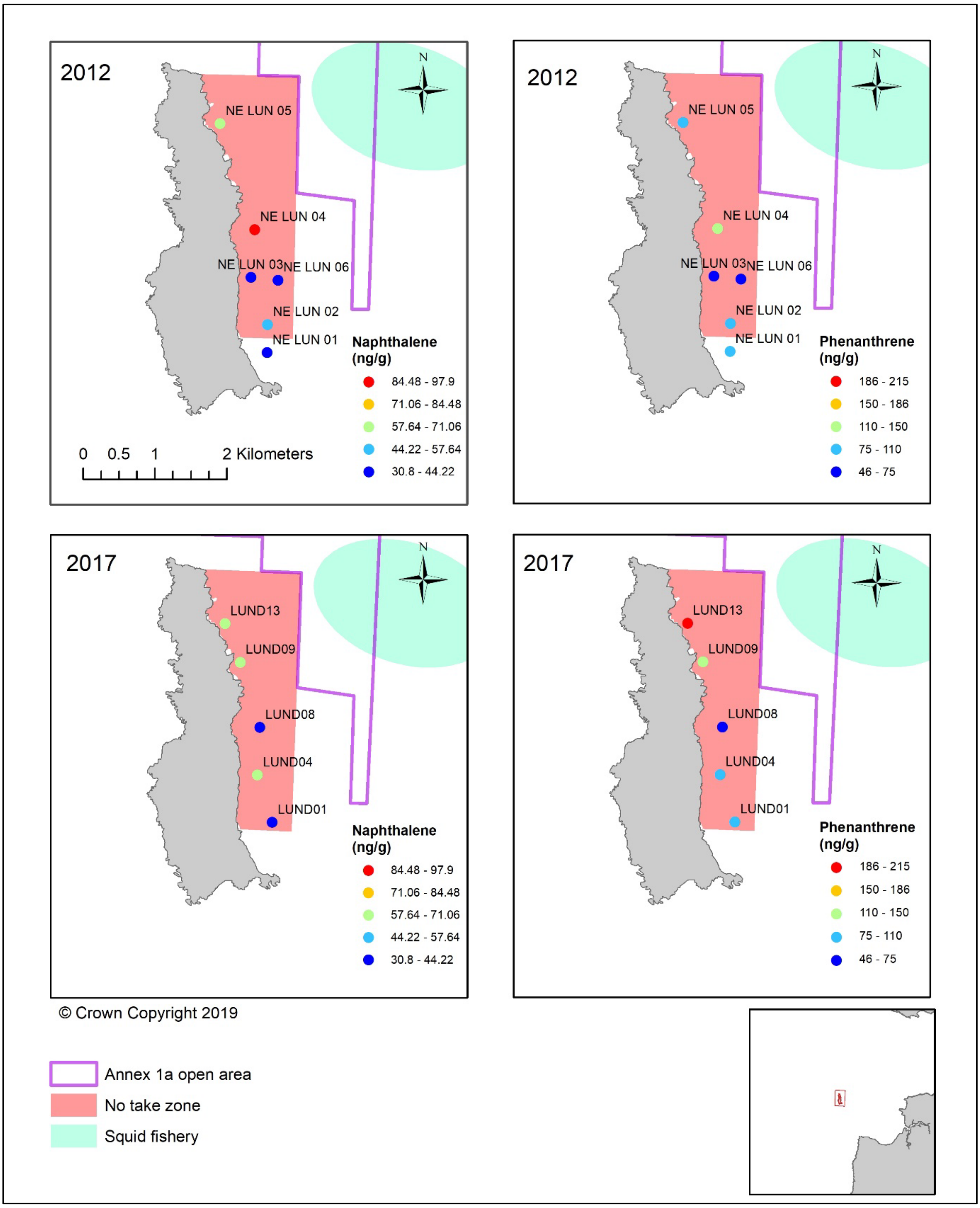

Figure 49. Sediment PAH concentrations for Naphthalene and Phenanthrene at Lundy SAC in 2012 and 2017 (© Natural England and Cefas 2022).

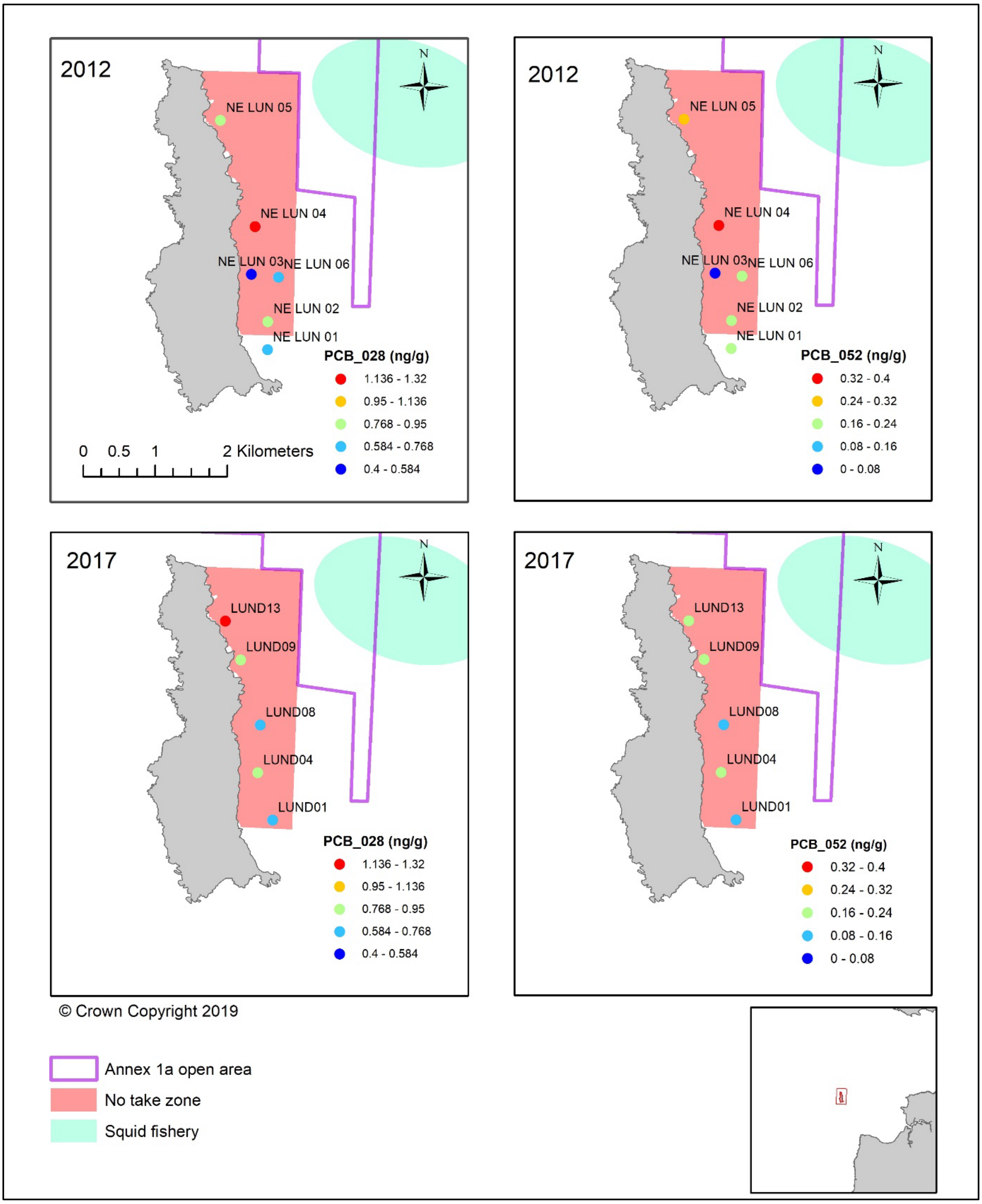

Figure 50. Sediment PCB concentrations for congeners PCB-028 and PCB-052 at Lundy SAC in 2012 and 2017 (© Natural England and Cefas 2022).

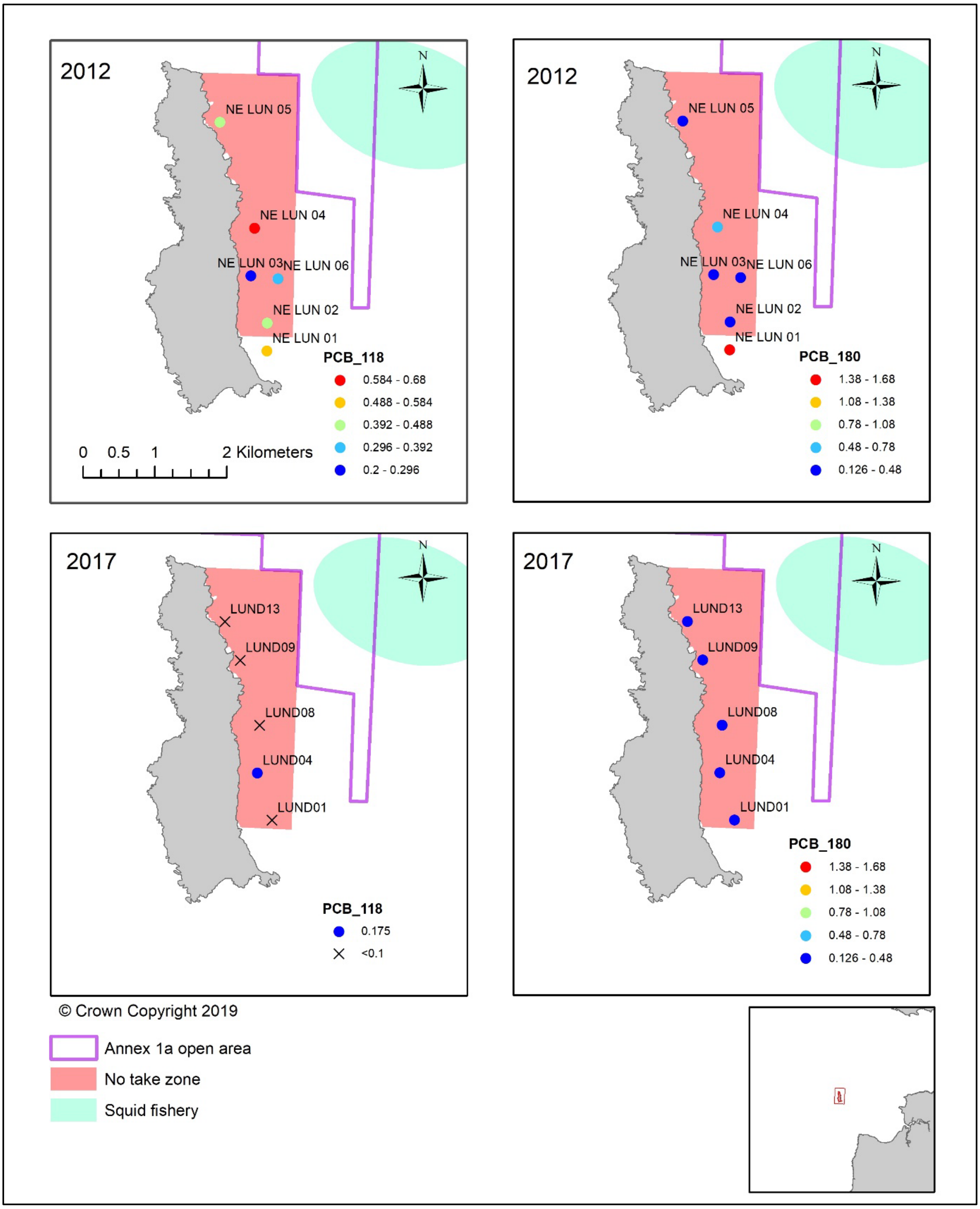

Figure 51. Sediment PCB concentrations for congeners PCB-118 and PCB-180 at Lundy SAC in 2012 and 2017 (© Natural England and Cefas 2022).

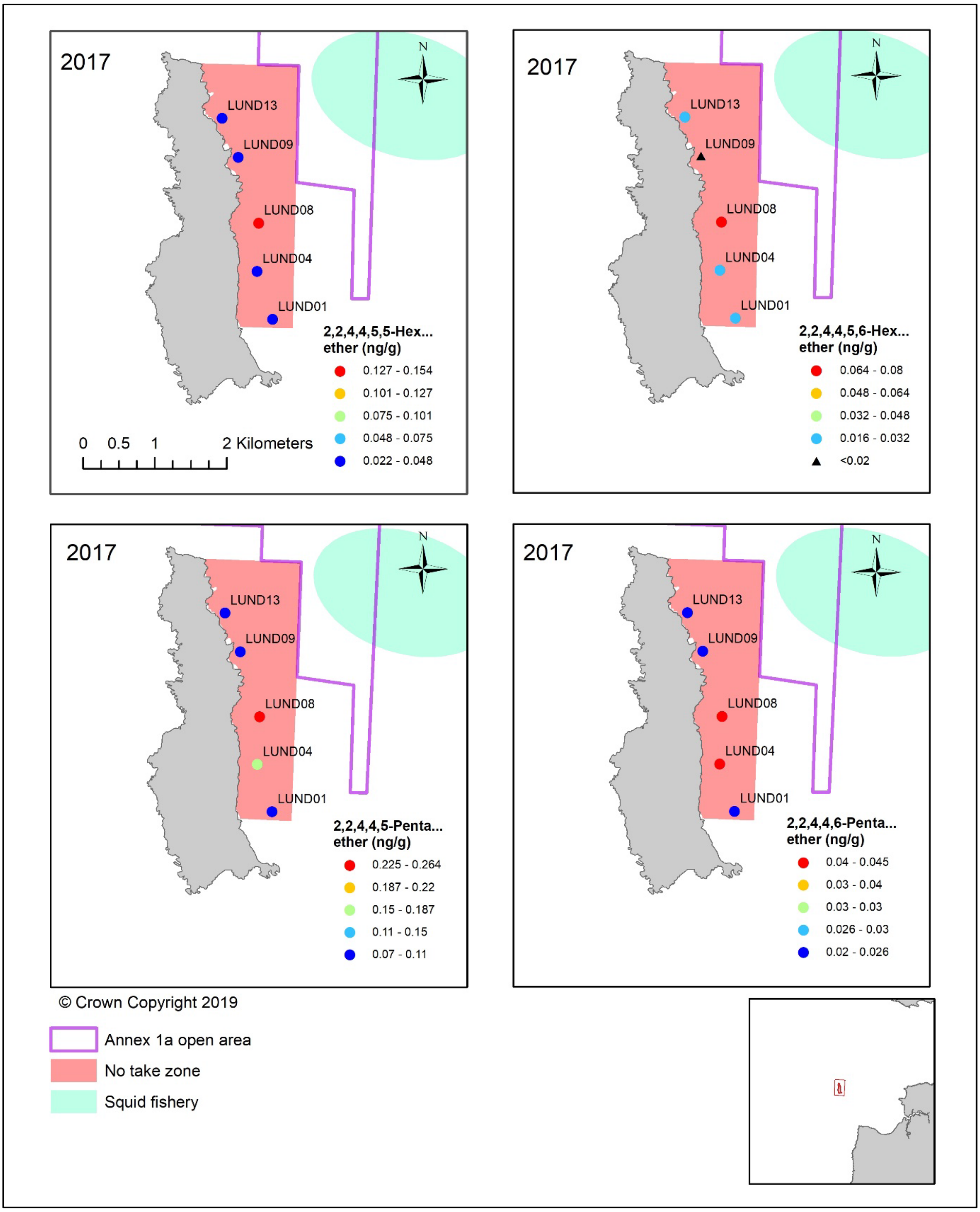

Figure 52. Sediment PBDE concentrations for PBDE 153, PBDE 154, PBDE 99 and PBDE 100 at Lundy SAC in 2017 (© Natural England and Cefas 2022).

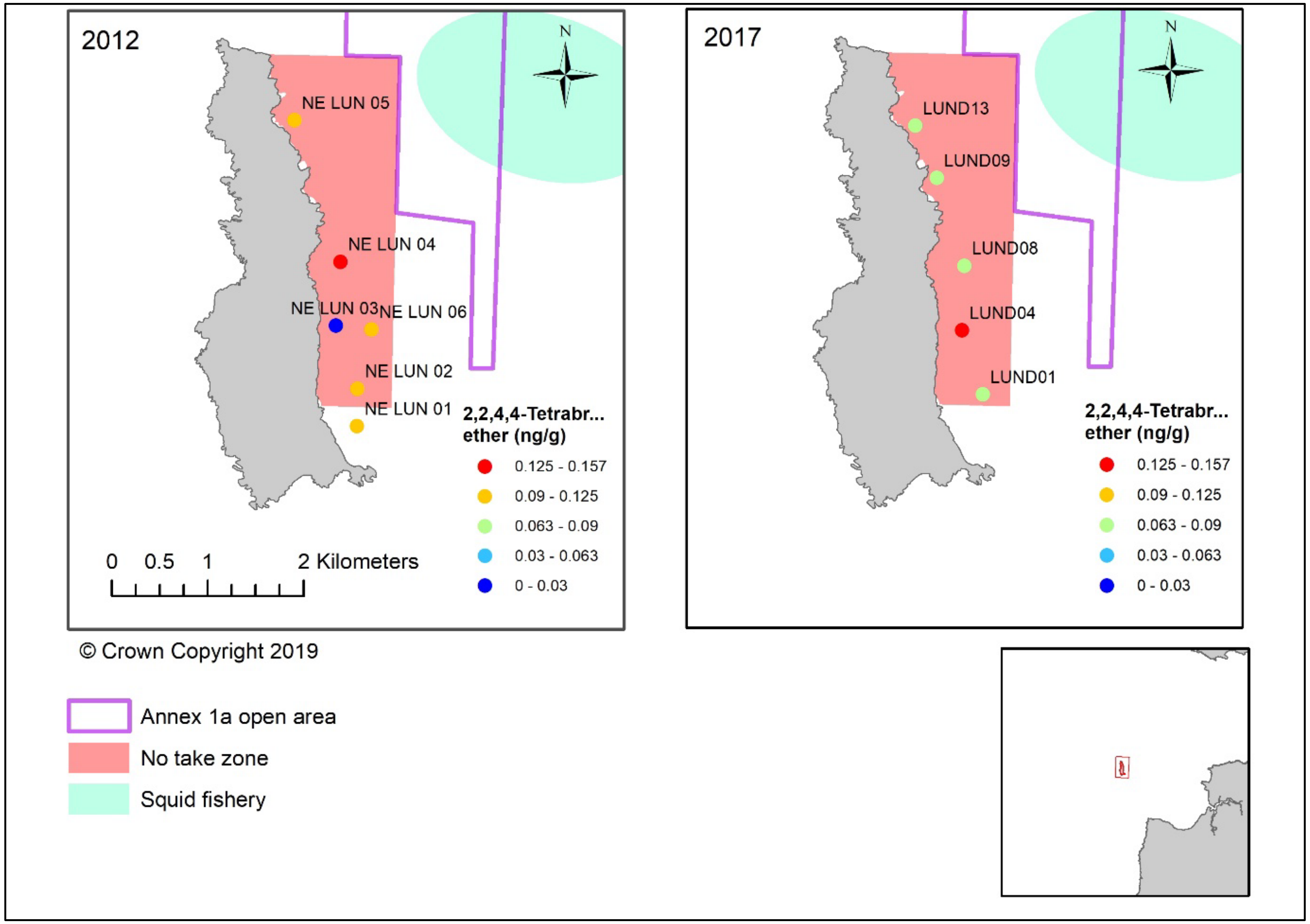

Figure 53. Sediment PBDE concentrations for PBDE 47 at Lundy SAC in 2012 and 2017 (© Natural England and Cefas 2022).

Appendix 7. Objective 3: Details of the univariate metrics of community structure, total wet biomass and multivariate community structure for each of the intensively sampled boxes within each of the fishery management zones (Zones 1, 2 and 3)

Table 26. At the scale of intensively sampled boxes (© Natural England and Cefas 2022).

Fisheries management zone	Station code		Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
Zone 1	LUND30	Min.	45.0	65.0	0.9	0.4
		1stQu.	49.0	71.0	0.9	0.6
		Median	64.0	113.0	0.9	0.8
		Mean	61.6	107.4	0.9	1.1
		3rdQu.	68.0	139.0	0.9	1.0
		Max.	82.0	149.0	1.0	2.7
		St. dev	15.0	38.4	0.0	0.9
	LUND31	Min.	37.0	74.0	0.7	0.6
		1stQu.	39.0	115.0	0.7	0.7
		Median	43.0	130.0	0.8	0.8
		Mean	45.2	148.6	0.8	1.7
		3rdQu.	49.0	164.0	0.8	1.2
		Max.	58.0	260.0	0.9	5.4
		St. dev	8.5	70.2	0.1	2.1
	LUND32	Min.	71.0	181.0	0.6	0.7
		1stQu.	72.0	183.0	0.8	1.9
		Median	100.0	300.0	0.8	2.5
		Mean	90.2	288.0	0.8	2.5
		3rdQu.	101.0	308.0	0.9	3.8
		Max.	107.0	468.0	0.9	3.8
		St. dev	17.3	117.7	0.1	1.3
	LUND56	Min.	69.0	122.0	0.9	1.6
		1stQu.	72.0	159.0	0.9	2.5
		Median	73.0	168.0	0.9	3.3
		Mean	73.8	163.6	0.9	4.8

Fisheries management zone	Station code		Species richness (S)	Abundance (N)	Pielou's evenness (j')	Total biomass (g)
		3rdQu.	76.0	180.0	0.9	7.1
		Max.	79.0	189.0	0.9	9.3
		St. dev	3.8	25.9	0.0	3.3
Zone 2	LUND36	Min.	47.0	119.0	0.6	0.8
		1stQu.	53.0	135.0	0.7	1.6
		Median	63.0	267.0	0.8	2.7
		Mean	64.8	231.8	0.8	2.8
		3rdQu.	74.0	281.0	0.8	2.8
		Max.	87.0	119.0	0.9	6.0
		St. dev	16.1	101.8	0.1	2.0
	LUND39	Min.	50.0	357.0	0.8	1.5
		1stQu.	50.0	94.0	0.8	1.6
		Median	52.0	127.0	0.9	2.5
		Mean	51.8	151.0	0.8	2.5
		3rdQu.	53.0	146.0	0.9	3.2
		Max.	54.0	166.0	0.9	3.6
		St. dev	1.8	37.4	0.1	0.9
	LUND48	Min.	66.0	120.0	0.7	0.8
		1stQu.	75.0	191.0	0.8	1.0
		Median	77.0	199.0	0.9	1.1
		Mean	82.2	252.4	0.8	1.7
		3rdQu.	79.0	210.0	0.9	2.6
		Max.	114.0	542.0	0.9	2.8
		St. dev	18.5	165.7	0.1	1.0
	LUND55	Min.	43.0	99.0	0.8	2.2
		1stQu.	53.0	155.0	0.8	2.5
		Median	60.0	172.0	0.8	3.1
		Mean	64.2	220.4	0.8	3.2
		3rdQu.	80.0	302.0	0.9	3.3
		Max.	85.0	374.0	0.9	4.7
		St. dev	17.9	113.6	0.1	1.0
Zone 3	LUND05	Min.	31.0	54.0	0.6	0.6
		1stQu.	48.0	146.0	0.7	0.8
		Median	49.0	199.0	0.8	1.6
		Mean	47.0	168.6	0.8	1.6
		3rdQu.	51.0	204.0	0.9	2.4
		Max.	56.0	240.0	0.9	2.6
		St. dev	9.5	72.3	0.1	0.9
	LUND08	Min.	35.0	69.0	0.8	1.5

Fisheries management zone	Station code		Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
		1stQu.	46.0	114.0	0.8	1.7
		Median	48.0	168.0	0.8	2.2
		Mean	50.0	146.0	0.8	2.0
		3rdQu.	59.0	185.0	0.8	2.2
		Max.	62.0	194.0	0.8	2.3
		St. dev	10.8	53.1	0.0	0.4
	LUND10	Min.	32.0	81.0	0.7	0.7
		1stQu.	38.0	83.0	0.8	0.8
		Median	43.0	155.0	0.8	1.4
		Mean	44.0	132.6	0.8	1.9
		3rdQu.	45.0	157.0	0.9	2.2
		Max.	62.0	187.0	0.9	4.3
		St. dev	11.3	47.9	0.1	1.5
	LUND15	Min.	89.0	186.0	0.8	1.2
		1stQu.	93.0	253.0	0.8	3.5
		Median	101.0	286.0	0.8	3.9
		Mean	100.4	293.0	0.8	3.4
		3rdQu.	104.0	362.0	0.9	4.0
		Max.	115.0	378.0	0.9	4.3
		St. dev	10.1	79.2	0.1	1.3

Table 27. At the scale of fishery management zone (intensively sampled boxes) (© Natural England and Cefas 2022).

Fisheries management zone		Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
Zone 1 (n = 20)	Min.	37.0	65.0	0.6	0.4
	1stQu.	49.0	120.2	0.8	0.8
	Median	70.0	161.5	0.9	1.8
	Mean	67.7	176.9	0.9	2.5
	3rdQu.	76.8	184.5	0.9	3.4
	Max.	107.0	468.0	1.0	9.3
	St. dev	20.4	95.8	0.1	2.4
Zone 2 (n = 20)	Min.	43.0	94.0	0.6	0.8
	1stQu.	52.8	133.0	0.8	1.6
	Median	61.5	181.5	0.8	2.6
	Mean	65.8	212.7	0.8	2.5
	3rdQu.	77.5	270.5	0.9	3.1

Fisheries management zone		Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
	Max.	114.0	542.0	0.9	6.0
	St. dev	17.8	112.6	0.1	1.3
Zone 3 (n = 20)	Min.	31.0	54.0	0.6	0.6
	1stQu.	44.5	138.0	0.8	1.4
	Median	50.0	185.5	0.8	2.2
	Mean	60.4	185.1	0.8	2.2
	3rdQu.	68.8	213.0	0.9	2.8
	Max.	115.0	378.0	0.9	4.3
	St. dev	25.7	88.1	0.1	1.2

Table 28. SIMPER outputs for differences between fishery management zones of infaunal assemblage structure based on data from the intensively sampled boxes at Lundy, 2017 (© Natural England and Cefas 2022).

Pairwise comparison	Species	Zone 1	Zone 2	Zone 3	Av. Diss	Contrib. %	Cum. %
Zone 1 & Zone 2 Average dissimilarity = 71.62	*Spisula*	0.8	0.2	N/A	0.6	0.9	0.9
	Lysidice unicornis	0.3	0.8	N/A	0.6	0.9	1.8
	Caulleriella alata	0.2	0.9	N/A	0.6	0.8	2.6
	Timoclea ovata	0.6	0.8	N/A	0.6	0.8	3.4
	Nemertea	1.8	1.8	N/A	0.6	0.8	4.2
	Mediomastus fragilis	0.3	0.9	N/A	0.6	0.8	5.0
	Corbula gibba	0.2	0.7	N/A	0.6	0.8	5.8
	Aglaophamus agilis	0.7	0.1	N/A	0.6	0.8	6.6
	Scalibregmatidae	0.1	0.7	N/A	0.6	0.8	7.4
	Spiophanes bombyx	0.7	0.2	N/A	0.6	0.8	8.2
	Lumbrineris cingulata agg.	0.9	1.2	N/A	0.6	0.8	9.0
	Magelona alleni	0.2	0.7	N/A	0.6	0.8	9.8
	Glycera lapidum agg.	1.0	0.6	N/A	0.5	0.8	10.5
	Ampelisca spinipes	0.8	0.3	N/A	0.5	0.8	11.3

Pairwise comparison	Species	Zone 1	Zone 2	Zone 3	Av. Diss	Contrib. %	Cum. %
	Echinocyamus pusillus	1.2	0.9	N/A	0.5	0.8	12.0
Zone 3 & Zone 1 Average dissimilarity = 74.37	*Echinocyamus pusillus*	1.2	N/A	0.5	0.9	1.2	1.2
	Euclymeninae	0.2	N/A	1.0	0.8	1.1	2.3
	Glycera lapidum agg.	1.0	N/A	0.4	0.7	1.0	3.2
	Magelona alleni	0.2	N/A	0.9	0.7	1.0	4.2
	Spisula	0.8	N/A	0.2	0.7	0.9	5.2
	Lumbrineris cingulata agg.	0.9	N/A	1.5	0.7	0.9	6.1
	Nemertea	1.8	N/A	2.0	0.6	0.9	6.9
	Peresiella clymenoides	0.1	N/A	0.7	0.6	0.9	7.8
	Ampelisca spinipes	0.8	N/A	0.3	0.6	0.8	8.6
	Leiochone	0.4	N/A	0.8	0.6	0.8	9.4
	Aglaophamus agilis	0.7	N/A	0.2	0.6	0.8	10.2
	Spiophanes bombyx	0.7	N/A	0.5	0.6	0.8	11.0
	Podarkeopsis capensis	0.0	N/A	0.6	0.6	0.8	11.7
	Mediomastus fragilis	0.3	N/A	0.9	0.6	0.7	12.5
	Timoclea ovata	0.6	N/A	0.5	0.6	0.7	13.2
Zone 3 and Zone 2 Average dissimilarity = 67.83	*Echinocyamus pusillus*	N/A	0.9	0.5	0.7	1.1	1.1
	Lysidice unicornis	N/A	0.8	0.3	0.7	1.0	2.0
	Timoclea ovata	N/A	0.8	0.5	0.6	0.9	2.9
	Nemertea	N/A	1.8	2.0	0.6	0.9	3.8
	Scalibregmatidae	N/A	0.7	0.6	0.6	0.9	4.7
	Peresiella clymenoides	N/A	0.3	0.7	0.6	0.9	5.5
	Magelona alleni	N/A	0.7	0.9	0.6	0.9	6.4
	Corbula gibba	N/A	0.7	0.5	0.6	0.8	7.2
	Podarkeopsis capensis	N/A	0.1	0.6	0.6	0.8	8.1
	Leiochone	N/A	0.5	0.8	0.6	0.8	8.9

Pairwise comparison	Species	Zone 1	Zone 2	Zone 3	Av. Diss	Contrib. %	Cum. %
	Glycera lapidum agg.	N/A	0.6	0.4	0.6	0.8	9.7
	Bivalvia	N/A	0.7	0.6	0.6	0.8	10.5
	Lumbrineris cingulata agg.	N/A	1.2	1.5	0.5	0.8	11.3
	Glycinde nordmanni	N/A	0.5	0.4	0.5	0.8	12.1
	Ampelisca	N/A	0.5	0.5	0.5	0.8	12.9

Appendix 8. Objective 4: Details of the univariate metrics of community structure, total wet biomass and multivariate community structure based on single sample spatial stations sampled across Lundy SAC, 2017

Table 29. Univariate metric values across fishery management zones (spatial stations) (© Natural England and Cefas 2022).

Fisheries management zone	Statistic	Species richness (*S*)	Abundance (*N*)	Pielou's evenness (*j'*)	Total biomass (g)
Zone 1 (n = 19)	Min.	2.0	2.0	0.5	0.0
	1stQu.	42.5	69.5	0.8	0.6
	Median	49.0	116.0	0.9	1.8
	Mean	54.4	149.5	0.9	2.3
	3rdQu.	73.5	213.5	0.9	3.5
	Max.	101.0	491.0	1.0	7.8
	St. dev	27.3	118.9	0.1	2.1
Zone 2 (n = 16)	Min.	11.0	12.0	0.5	0.0
	1stQu.	29.8	105.8	0.8	1.3
	Median	56.0	161.5	0.8	2.2
	Mean	51.6	167.4	0.8	2.2
	3rdQu.	64.8	219.2	0.8	2.8
	Max.	93.0	357.0	1.0	6.6
	St. dev	24.0	91.3	0.1	1.6
Zone 3 (n = 15)	Min.	14.0	26.0	0.7	0.4
	1stQu.	31.0	54.5	0.8	1.2
	Median	43.0	93.0	0.9	1.6
	Mean	46.3	113.6	0.9	2.3
	3rdQu.	56.0	155.5	0.9	3.6
	Max.	104.0	362.0	1.0	5.0
	St. dev	25.0	86.2	0.1	1.5

Table 30. SIMPER outputs indicating the top 15 most important taxa discriminating between assemblages of the three fishery management zones based on data from single samples across the Lundy SAC, 2017 (© Natural England and Cefas 2022).

Pairwise comparison	Species	Zone 1	Zone 2	Zone 3	Av. Diss	Contrib %	Cum.%
Groups Zone 1 & Zone 2 Average dissimilarity = 79.78	*Lumbrineris cingulata* agg.	0.4	1.0	N/A	0.9	1.1	1.1
	Nemertea	0.8	1.2	N/A	0.8	1.0	2.1
	Magelona alleni	0.1	0.7	N/A	0.7	0.9	3.0
	Glycera lapidum agg.	0.8	0.7	N/A	0.7	0.9	3.9
	Crisiidae	1.0	0.7	N/A	0.7	0.9	4.8
	Schizomavella	0.8	0.2	N/A	0.7	0.9	5.6
	Bicellariella ciliata	0.6	0.7	N/A	0.7	0.8	6.5
	Scalibregma inflatum	0.1	0.7	N/A	0.7	0.8	7.3
	Sertulariidae	0.7	0.9	N/A	0.7	0.8	8.1
	Corbula gibba	0.1	0.6	N/A	0.6	0.8	8.9
	Amathia	0.6	0.5	N/A	0.6	0.8	9.7
	Electra pilosa	0.7	0.3	N/A	0.6	0.8	10.4
	Bugulidae	0.8	1.0	N/A	0.6	0.8	11.2
	Candidae	0.7	0.5	N/A	0.6	0.8	12.0
	Aglaophamus agilis	0.6	0.0	N/A	0.6	0.8	12.7
Groups Zone 3 & Zone 1 Average dissimilarity = 81.71	*Lumbrineris cingulata* agg.	0.4	N/A	0.8	0.9	1.1	1.1
	Glycera lapidum agg.	0.8	N/A	0.3	0.9	1.1	2.2
	Euclymeninae	0.1	N/A	0.7	0.9	1.1	3.2
	Maldanidae	0.5	N/A	0.9	0.9	1.0	4.3
	Praxillella affinis	0.1	N/A	0.7	0.8	1.0	5.2
	Candidae	0.7	N/A	0.5	0.8	1.0	6.2
	Peresiella clymenoides	0.1	N/A	0.7	0.8	1.0	7.2
	Scalibregma inflatum	0.1	N/A	0.6	0.8	0.9	8.1
	Crisidia cornuta	0.5	N/A	0.4	0.7	0.9	9.0
	Bugulidae	0.8	N/A	0.9	0.7	0.9	9.9
	Schizomavella	0.8	N/A	0.3	0.7	0.9	10.8
	Sertulariidae	0.7	N/A	0.4	0.7	0.9	11.7
	Nemertea	0.8	N/A	0.9	0.7	0.9	12.6
	Electra pilosa	0.7	N/A	0.3	0.7	0.8	13.4

Pairwise comparison	Species	Zone 1	Zone 2	Zone 3	Av. Diss	Contrib %	Cum.%
	Aglaophamus agilis	0.6	N/A	0.1	0.7	0.8	14.2
Groups Zone 3 & Zone 2 Average dissimilarity = 76.93	Sertulariidae	N/A	0.91	0.36	0.89	1.16	1.16
	Nemertea	N/A	1.2	0.9	0.8	1.1	2.3
	Crisiidae	N/A	0.7	0.8	0.8	1.0	3.3
	Maldanidae	N/A	0.6	0.9	0.8	1.0	4.3
	Euclymeninae	N/A	0.4	0.7	0.8	1.0	5.3
	Peresiella clymenoides	N/A	0.1	0.7	0.8	1.0	6.3
	Praxillella affinis	N/A	0.3	0.7	0.8	1.0	7.3
	Magelona alleni	N/A	0.7	0.6	0.7	0.9	8.2
	Bicellariella ciliata	N/A	0.7	0.4	0.7	0.9	9.2
	Glycera lapidum agg.	N/A	0.7	0.3	0.7	0.9	10.1
	Ophiuroidea	N/A	0.6	0.1	0.7	0.9	10.9
	Lumbrineris cingulata agg.	N/A	1.0	0.8	0.7	0.9	11.8
	Crisidia cornuta	N/A	0.5	0.4	0.7	0.9	12.7
	Candidae	N/A	0.5	0.5	0.7	0.9	13.6
	Amphiura filiformis	N/A	0.5	0.4	0.7	0.9	14.5

Annex 1. Glossary

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

Activity	A human action which may have an effect on the marine environment; e.g. fishing, energy production (Robinson, Rogers and Frid, 2008).*
Annex	Addition to a document or a report from another source.
Annex I Habitats	Habitats of conservation importance listed in Annex I of the EC Habitats Directive, for which SAC are designated.
Anthropogenic	Caused by humans or human activities; usually used in reference to environmental degradation.*
Appendix	A section or table of subsidiary matter at the end of a report that includes additional information or data to the reader.
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).*

EC Habitats Directive	The EC Habitats Directive (Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora) requires Member States to take measures to maintain natural habitats and wild species of European importance at, or restore them to, favourable conservation status.
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 SACO. Feature Attributes are monitored to determine whether condition is favourable.
Features of Conservation Importance (FOCI)	Habitats and species that are rare, threatened or declining in Secretary of State waters.*
General Management Approach (GMA)	The management approach required to achieve favourable condition at the site level; either maintain in, or recover to favourable condition.
Habitats of Conservation Importance (HOCI)	Habitats that are rare, threatened, or declining in Secretary of State waters.*
Impact	The consequence of pressures (e.g. habitat degradation) where a change occurs that is different to that expected under natural conditions (Robinson *et al.*, 2008).*
Infauna	Fauna living within the seabed sediment.
Joint Nature Conservation Committee (JNCC)	The statutory adviser to Government on UK and international nature conservation. Its specific remit in the marine environment ranges from 12 - 200 nm offshore.

Marine Strategy Framework Directive (MSFD)	The MSFD (EC Directive 2008/56/EC) aims to achieve Good Environmental Status (GES) of EU marine waters and to protect the resource base upon which marine-related economic and social activities depend.
Marine Conservation Zone (MCZ)	MPAs designated under the Marine and Coastal Access Act (2009). MCZs protect nationally important marine wildlife, habitats, geology and geomorphology, and can be designated anywhere in English and Welsh inshore and UK offshore waters.*
Marine Protected Area (MPA)	A generic term to cover all marine areas that are 'A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values' (Dudley, 2008).*
Natura 2000	The EU network of nature protection areas (classified as Special Areas of Conservation and Special Protection Areas), established under the 1992 EC Habitats Directive.*
Natural England	The statutory conservation adviser to Government, with a remit for England out to 12 nm offshore.
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).*
Special Areas of Conservation	Protected sites designated under the European Habitats Directive for species and habitats of European importance, as listed in Annex I and II of the Directive.*
Species of Conservation Importance (SOCI)	Habitats and species that are rare, threatened or declining in Secretary of State waters.*
Supplementary Advice on Conservation Objectives (SACO)	Site-specific advice providing more detailed information on the ecological characteristics or 'attributes' of the site's designated feature(s). This advice is issued by Natural England and/or JNCC.

Annex 2. Non-indigenous species (NIS) lists

Table 31. Taxa listed as NIS (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
Magallana angulata	Present	*Celtodoryx ciocalyptoides*	Horizon
Magallana gigas	Present	*Chama* sp.	Horizon
Crepidula fornicata	Present	*Dendostrea frons*	Horizon
Diadumene lineata	Present	*Agarophyton vermiculophyllum*	Horizon
Didemnum vexillum	Present	*Hemigrapsus penicillatus*	Horizon
Dyspanopeus sayi	Present	*Hemigrapsus sanguineus*	Horizon
Ensis leei	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	*Ocinebrellus inornatus*	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 anglica	Present		
Styela clava	Present		
Undaria pinnatifida	Present		
Urosalpinx cinerea	Present		
Watersipora subatra	Present		

Table 32. Additional taxa listed as NIS in the JNCC ‘Non-native marine species in British waters: a review and directory’ report by Eno *et al*. (1997) which have not been selected for assessment of Good Environmental Status in GB waters under MSFD.

Species name (1997)	Updated name (2020)
Thalassiosira punctigera	*Ethmodiscus punctiger*
Thalassiosira tealata	N/A
Coscinodiscus wailesii	N/A
Odontella sinensis	*Biddulphia sinensis*
Pleurosigma simonsenii	N/A
Grateloupia doryphora	N/A
Grateloupia filicina var. *luxurians*	*Grateloupia subpectinata*
Pikea californica	N/A
Agardhiella subulata	N/A
Solieria chordalis	N/A
Antithamnionella spirographidis	N/A
Antithamnionella ternifolia	N/A
Polysiphonia harveyi	*Melanothamnus harveyi*
Colpomenia peregrina	N/A
Codium fragile subsp. *atlanticum*	N/A
Codium fragile subsp. *tomentosoides*	*Codium fragile* subsp. *fragile*
Gonionemus vertens	N/A
Clavopsella navis	*Pachycordyle michaeli*
Anguillicoloides crassus	N/A
Goniadella gracilis	N/A
Marenzelleria viridis	N/A
Clymenella torquata	N/A
Hydroides dianthus	N/A
Hydroides ezoensis	N/A
Janua brasiliensis	*Neodexiospira brasiliensis*
Pileolaria berkeleyana	N/A
Ammothea hilgendorfi	N/A

Species name (1997)	Updated name (2020)
Elminius modestus	*Austrominius modestus*
Eusarsiella zostericola	
Corophium sextonae	*Monocorophium sextonae*
Rhithropanopeus harrisii	
Potamopyrgus antipodarum	
Tiostrea lutaria	*Ostrea chilensis*
Mercenaria mercenaria	
Petricola pholadiformis	*Petricolaria pholadiformis*
Mya arenaria	

Annex 3. 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	N/A	F4. Pallets
A5. Fishing line (monofilament)	B5. Appliances	C5. Other	N/A	N/A	F5. Other
A6. Fishing line (entangled)	B6. Car parts	N/A	N/A	N/A	N/A
A7. Synthetic rope	B7. Cables	N/A	N/A	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	
A8. Fishing net	B8. Other	N/A	N/A		
A9. Cable ties	N/A	N/A	N/A		
A10. Strapping band	N/A	N/A	N/A		
A11. Crates and containers	N/A	N/A	N/A		

A: Plastic	B: Metals	C: Rubber	D: Glass/ Ceramics	E: Natural products/ Clothes	F: Miscellaneous
A12. Plastic diapers	N/A	N/A	N/A	N/A	N/A
A13. Sanitary towels/ tampons	N/A	N/A	N/A	N/A	N/A
A14. Other	N/A	N/A	N/A	N/A	N/A

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