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Wight-Barfleur Reef Special Area of Conservation (SAC) Characterisation Report 2017

Downie, A., Arosio, R. & McBreen, F.

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For further information please contact:
Joint Nature Conservation Committee
Monkstone House
City Road
Peterborough PE1 1JY
www.jncc.gov.uk

Marine Monitoring Team (marinemonitoring@jncc.gov.uk)

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Seacole Block
2 Marsham Street
London SW1P 4DF

Please Note:
This work was delivered by Cefas and JNCC on behalf of the Marine Protected Areas Survey Coordination & Evidence Delivery Group (MPAG) and sponsored by Defra. MPAG was established in November 2012 and continued until March 2020. MPAG, was originally established to deliver evidence for Marine Conservation Zones (MCZs) recommended for designation. In 2014, the programme of work was refocused towards delivering the evolving requirements for Marine Protected Area (MPA) data and evidence gathering to inform the assessment of the condition of designated sites and features by SNCBs, in order to inform Secretary of State reporting to Parliament. MPAG was primarily comprised of members from Defra and its delivery bodies which have MPA evidence and monitoring budgets and/or survey capability. Members included representatives from Defra, JNCC, Natural England, Cefas, the Environment Agency, the Inshore Fisheries Conservation Authorities (IFCAs) and the Marine Management Organisation (MMO)).

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

Executive Summary

This report explores data acquired from a survey of Wight-Barfleur Reef offshore Special Area of Conservation (SAC) in 2017, which will form part of the ongoing time series data and evidence for this Marine Protected Area (MPA). Wight-Barfleur Reef SAC is located in the central English Channel and is designated for Annex I Reef habitats, containing both the bedrock and stony reef forms.

Wight-Barfleur Reef SAC is situated in a moderate to high energy environment, with a tidal model showing weak to moderately strong tidal flows but known high shear stress at the seabed. The structure of the Annex I Reef within the SAC varies between exposed bedrock, stony reef formed of a mosaic of boulders, cobbles and shallow sand deposits, and coarse sediment, forming ridges and flat inclined planes. Annex I Reef was observed at all stations where imagery data were acquired. The mosaic nature of the reef with narrow bedrock ridges interspersed with cobble reef and sediments makes it difficult to map accurately using acoustic data.

The existing Defra Digital Elevation Model (DEM) (Astrium 2011) interpretation of Annex I Reef was shown to be an approximate, but locally inaccurate, representation of the feature when compared to the results of object-based imagery analysis (OBIA) on acoustic and sample data from the 2017 survey. Using this higher resolution data, it was possible to delineate reef features at the scale of metres to tens of metres. Where information is needed on the fine scale rugosity or complexity of the reef habitats, fine scale topographic profiles, for example using altimeter and depth sensors on the camera frame, should be used in conjunction with imagery.

Reef epifauna displayed very high local variability in number of taxa, epifaunal coverage, and community composition. The latter two measures were affected by the availability and type of hard substrata, the fine scale topography of the reef and the location of the transect on the bottom, top or mid-slope of the wider reef structure. Seven statistically significant community groups were identified from cluster analysis of the epifaunal data. These groups exist along a continuum of increasing assemblage diversity and abundance, from flat cobble reef to structurally complex high relief reef. All the groups comprised variations of typical rocky reef sessile epifauna with different proportions of sponges, ascidians, anthozoans, hard and soft bryozoans, and hydrozoans. Community composition and taxon richness of epifauna were not found to be significantly different between bedrock and stony reef types, although there was significant topographical variation within these two categories. No OSPAR Threatened and/or Declining species or non-indigenous species were observed, although litter was recorded at 19 sampling locations.

A set of monitoring recommendations is presented for the Annex I Reef features within Wight-Barfleur Reef SAC (and other comparable sites), and the potential development of community structure, diversity and total epifaunal coverage as indicators of condition is discussed.

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Abbreviations

ANOSIM	Analysis of Similarity
BPI	Bathymetric Position Index
CATAMI	Collaborative and Automated Tools for Tools for Analysis of Marine Imagery
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CP2	Charting Progress 2
Defra	Department for Environment, Food and Rural Affairs
DEM	Digital Elevation Model
df	Degrees of freedom
EC	European Community
Edf	Estimated degrees of freedom
EIP	Epifauna Identification Protocol
ESM2	Ecosystem Monitor 2 logger
E.U.	European Union
EUNIS	European Nature Information System
FOV	Field of View
GAM	General Additive Model
GES	Good Environmental Status
GIS	Geographic Information System
GPS	Global Positioning System
HD	High Definition
HiPAP	High Precision Acoustic Positioning
ICES	International Council for the Exploration of the Sea (ICES)
IBTS	International Bottom Trawl Survey
JNCC	Joint Nature Conservation Committee
MBES	Multibeam echosounder
MCZ	Marine Conservation Zone
MESH	Mapping European Seabed Habitats project
MMO	Marine Management Organisation
MNCR	Marine Nature Conservation Review
MPA	Marine Protected Area
MPAG	Marine Protected Areas Survey Coordination and Evidence Delivery Group
MRU	Motion Reference Unit
MSFD	Marine Strategy Framework Directive
NIS	Non-Indigenous Species
NMBAQC	North-East Atlantic Marine Biological Analytical Quality Control Scheme

nMDS	Non-metric Multidimensional Scaling
OBIA	Object-based Imagery Analysis
OSPAR	The Convention for the Protection of the Marine Environment of the North-East Atlantic
PRIMER	Plymouth Routines in Multivariate Ecological Research
ROG	Recommended Operating Guidelines
RV	Research Vessel
SAC	Special Area of Conservation
SACO	Supplementary Advice on Conservation Objectives
SACFOR	Superabundant-Abundant-Common-Frequent-Occasional-Rare scale
SAGA	System for Automated Geoscientific Analyses
SIMPER	Similarity Percentage analysis
SIMPROF	Similarity Profile analysis
SNCB	Statutory Nature Conservation Body
SPM	Suspended Particulate Matter
SSS	Sidescan sonar
TRI	Terrain Ruggedness Index
UBRE	Unbiased Risk Estimator score
UKHO	United Kingdom Hydrographic Office

Glossary

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

Activity	A human action which may have an effect on the marine environment; e.g. fishing, energy production (Robinson *et al*. 2008).*
Annex I Habitats	Habitats of conservation importance listed in Annex I of the EC Habitats Directive, for which Special Areas of Conservation (SAC) are designated.
Anthropogenic	Caused by humans or human activities; usually used in reference to environmental degradation.*
Assemblage	A collection of plants and/or animals characteristically associated with a particular environment that can be used as an indicator of that environment. The term has a neutral connotation and does not imply any specific relationship between the component organisms, whereas terms such as ‘community’ imply interactions (Allaby 2015).
Benthic	A description for animals, plants and habitats associated with the seabed. All plants and animals that live in, on or near the seabed are benthos (e.g. sponges, crabs, seagrass beds).*
Biotope	The physical habitat with its associated, distinctive biological communities. A biotope is the smallest unit of a habitat that can be delineated conveniently and is characterised by the community of plants and animals living there.*
Channel	A general term for an elongated bathymetric low.
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).*
Cretaceous Period	The last of the three periods of the Mesozoic Era, spanning from 145 to 66 million years before present.
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 Supplementary Advice on Conservation Objectives (SACO). Feature attributes are monitored to determine whether condition is favourable.
Impact	The consequence of pressures (e.g. habitat degradation) where a change occurs that is different to that expected under natural conditions (Robinson *et al*. 2008).*
Infauna	Fauna living within the seabed sediment.
Jurassic Period	The second of the three periods of the Mesozoic Era, spanning from 201 to 145 million years before present.
Marine Protected Area (MPA)	A generic term to cover all marine areas that are 'A clearly defined geographical space, recognised, dedicated and managed, through legal or other effective means, to achieve the long-term conservation of nature with associated ecosystem services and cultural values' (Dudley 2008).*
Marine Strategy Framework Directive (MSFD)	The MSFD (EC Directive 2008/56/EC) aims to achieve Good Environmental Status (GES) of EU marine waters and to protect the resource base upon which marine-related economic and social activities depend.
Megaripple	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 slopes, sharp peaks, and rounded troughs.
Natura 2000	The EU network of nature protection areas (classified as SAC and Special Protection Areas), established under the 1992 EC Habitats Directive.*
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).*
Paleovalley	A remnant of an inactive river or stream valley that has been possibly filled or buried by more recent sediments.
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).*

Quaternary Period	The current period of the Cenozoic Era, spanning from 2.6 million years ago to present.
Ridge	An elongated elevation of varying complexity, size and gradient, (length > width).
Sandwave	A sedimentary structure that forms from tidal currents. It consists of sand ridges with asymmetrical slopes and sharp peaks.
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.*
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.

1 Introduction

Wight-Barfleur Reef Special Area of Conservation (SAC) was designed to meet conservation objectives under the EC Habitats Directive (92/43/EEC). The SAC contributes to an ecologically coherent network of Marine Protected Areas (MPAs) across the North-east Atlantic, agreed under the OSPAR Convention and other international commitments to which the UK is signatory. This particular site is designated for the Annex I habitat 'Reefs'.

This report primarily explores data acquired from a 2017 survey of Wight-Barfleur Reef SAC. The specific aims of the report are discussed in more detail in Section 1.3.

1.1 Site overview

Wight-Barfleur Reef SAC is an offshore site located in the central English Channel, between St Catherine's point on the Isle of Wight and Barfleur Point on the Cotentin Peninsula in northern France (Figure 1).

It is located in the jurisdictional area of the Marine Management Organisation (MMO) and falls within the wider 'Charting Progress 2' (CP2) area 'Eastern Channel'. The site is neighboured by Offshore Overfalls Marine Conservation Zone (MCZ) and Offshore Brighton MCZ to the west and South Dorset MCZ to the east (Figure 1).

Wight-Barfleur SAC is sited ca. 25 km south of the Isle of Wight, in a bathymetrically irregular region of the English Channel/La Manche that is part of the Northern Paleovalley system, an unfilled paleodrainage network produced during the Quaternary period. Subaerial water erosion is the main cause for the presence of a thick network of meandering channels, scarps and scours in the region (Toucanne *et al*. 2010; Mellet *et al*. 2013). Water depths range from 25 m to 100 m below sea level (chart datum). The site is approximately 65 km long (east to west) and up to 26 km wide. The site was designated due to the presence of bedrock and stony reef features.

The large area of bedrock reef within the site is characterised by a series of well-defined exposed bedrock ridges, up to 4 m high.

The southern area of the site is composed of flat, smooth, mudstone and sandstone, with overlying coarse sediment (gravels, cobbles and boulders) which in places forms stony reef (Figure 2). The south-eastern area of the site contains part of a large palaeochannel, which forms a major depression running roughly north-east to south-west across the English Channel. In this area the palaeovalley remains largely unfilled by sediment due to strong currents and is also characterised by a gravel, cobble and boulder substrate which in places forms stony reef.

The bedrock and stony reef areas support a diverse range of reef fauna. Local spatial variability is high, forming a mosaic of assemblages that share many of their constituent taxa in varying ratios, depending on local substrate conditions and exposure to currents (Barrio-Froján *et al.* 2019). There are many forms of sponge present, from encrusting sponges to larger branching forms. Tube worms, anemones and tunicates (sea squirts) are also common on the large boulders and bedrock.

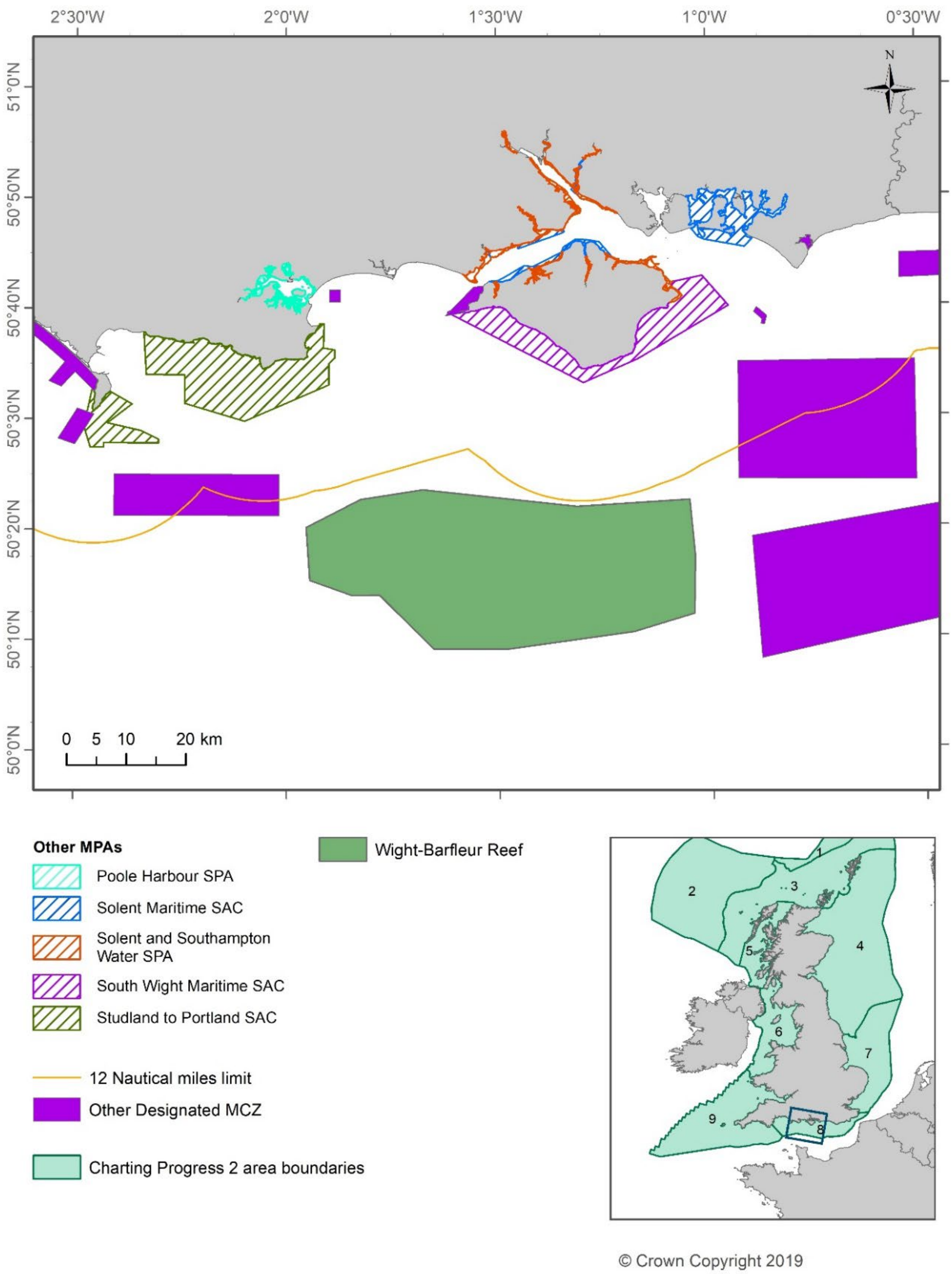

Figure 1. Location of the Wight-Barfleur Reef SAC in the context of MPAs and management jurisdictions proximal to the site.

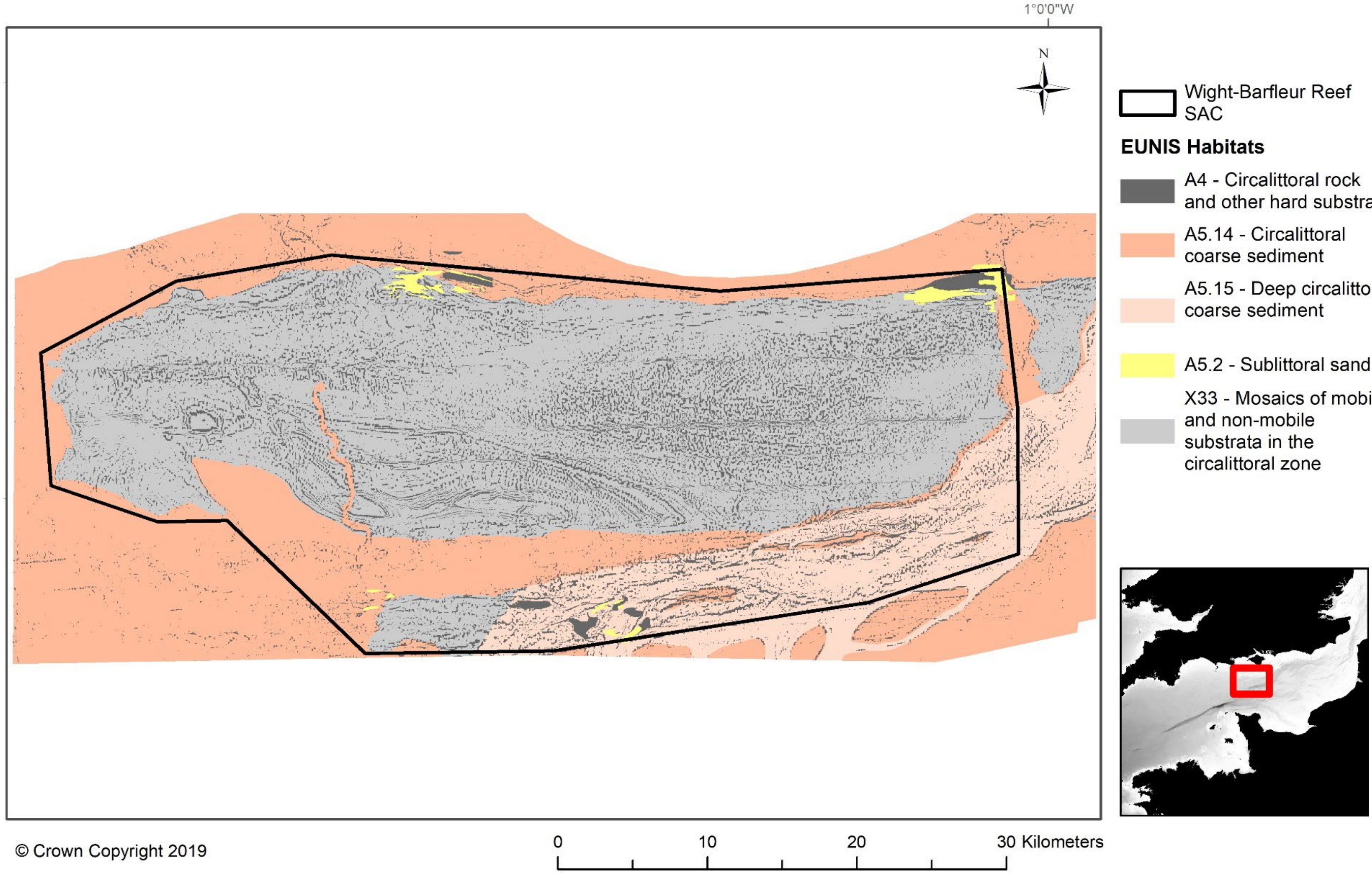

Figure 2. 2013 European Union Nature Identification System (EUNIS) map for the area in and around the Wight-Barfleur Reef SAC (after Barrio-Froján *et al*. 2019).

1.2 Existing data and habitat maps

In 2013 a dedicated benthic survey of the Wight-Barfleur Reef SAC acquired multibeam echosounder (MBES), sidescan sonar (SSS), and groundtruthing (grab and drop camera) data (Figure 3). Five areas were targeted for intensive survey, with 100% acoustic data coverage (Barrio-Froján *et al*. 2019).

A map of reef categories based on MBES acoustic features was not carried out, but manual interpretation of the SSS imagery with the aid of the groundtruthing data enabled the delineation of Annex I bedrock and boulder reef within the survey boxes. SSS returns throughout the Wight-Barfleur Reef SAC indicated a heterogeneous seabed dominated by bedrock and stony reef, with extensive areas consisting of a mosaic of hard and coarse substrates. Extrapolating the observations made within the intensely surveyed boxes, in conjunction with previous MBES data for greater coverage (2006 and 2012, cf. Barrio-Froján *et al*. 2019), the authors concluded that it is likely that stony reef, or a mosaic of stony reef and coarse sediment, is widespread throughout the SAC, in between the areas mapped as bedrock reef.

The 2013 data showed that the benthic community was very diverse across the entire survey area. Assemblages inhabiting sediment habitats were distinct from those inhabiting harder, more stable substrates, but the site was characterised by fine scale spatial heterogeneity, which makes detailed spatial representation of the different habitat types in maps unfeasible.

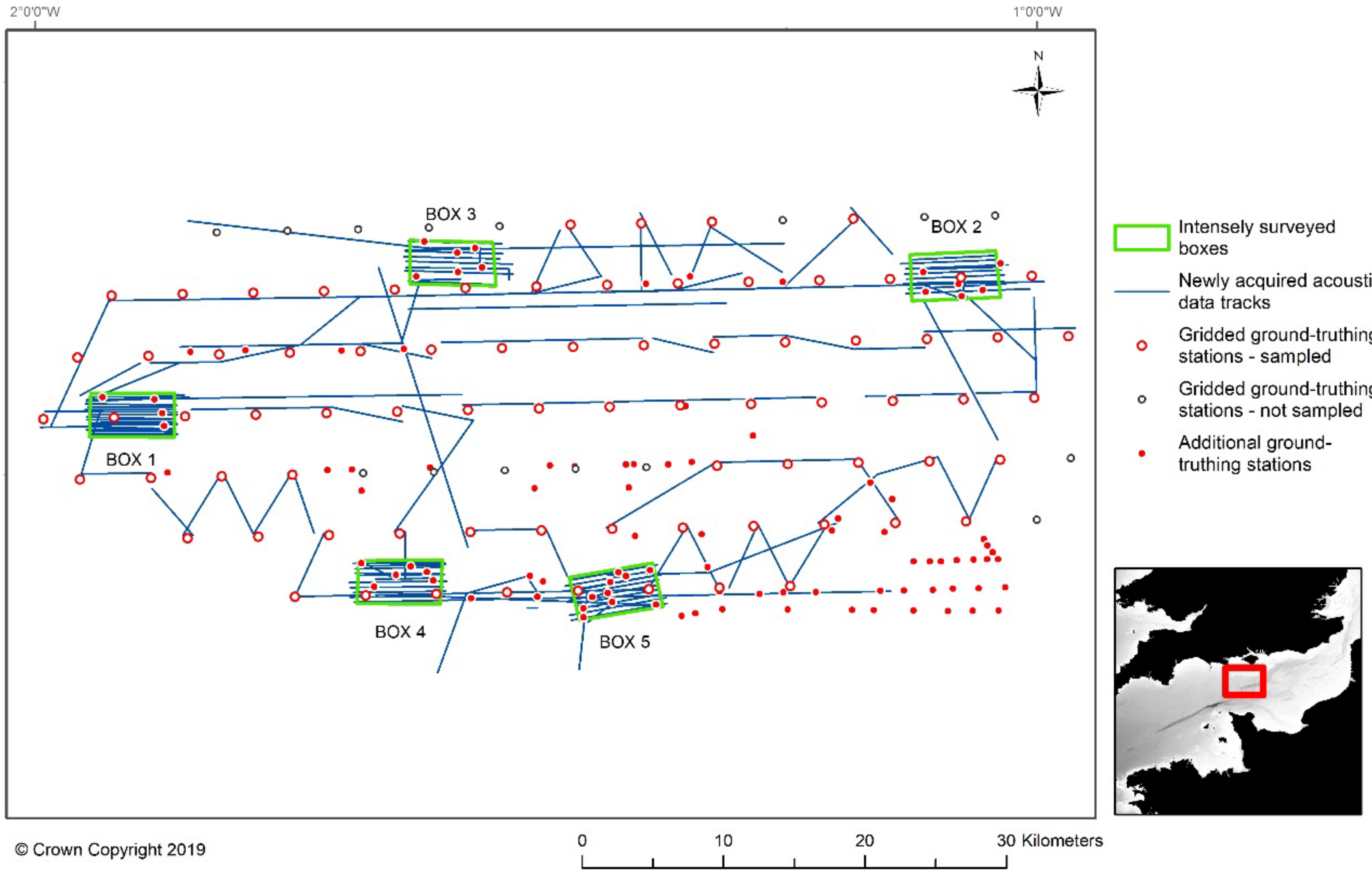

Figure 3. Acoustic and groundtruthing survey design executed at Wight-Barfleur Reef SAC in 2013 (after Barrio-Froján *et al*. 2019).

1.3 Aims and objectives

1.3.1 High-level Conservation Objective

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 condition'.

As detailed in the conservation advice package (JNCC 2018a), the Conservation Objective for the Wight-Barfleur Reef SAC is for the designated feature to be in favourable condition, thus ensuring site integrity in the long-term and contribution to Favourable Conservation Status of Annex I Reefs. This contribution would be achieved by maintaining or restoring, subject to natural change:

- The **extent and distribution** of the qualifying habitat in the site;
- The **structure and function** of the qualifying habitat in the site; and
- The **supporting processes** on which the qualifying habitat relies.

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

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

1.3.2 Report aims and objectives

The primary aim of this report is to explore and describe the attributes of the designated Annex I Reef feature within Wight-Barfleur Reef SAC. The results presented here will be used to develop recommendations for future monitoring and inform assessments of the condition of the feature.

The broad objectives of this report are listed below:

1) Provide a description of the **extent** and **distribution**, **structural** and (where possible) **functional attributes**, and the **supporting processes**, of the designated Annex I Reef feature within the SAC, using dedicated survey data collected in 2017 (see Table 1 for more detail), to enable subsequent condition monitoring and assessment;

2) Note observations of any OSPAR Threatened and/or Declining Habitats and Species not covered by the Designation Order as features of the site;

3) Present evidence relating to non-indigenous species (Descriptor 2) and marine litter (Descriptor 10), to satisfy requirements of the Marine Strategy Framework Directive;

4) Record any evidence of anthropogenic activities or impacts encountered during the 2017 survey;

5) Provide practical recommendations for appropriate future monitoring approaches for the designated features.

1.3.3 Reporting sub-objectives (Objective 1)

To achieve report Objective 1, a number of reporting sub-objectives will be addressed to provide evidence for feature attributes and supporting processes, as defined in SACO developed by JNCC for Wight-Barfleur Reef SAC (JNCC 2018b). It was not possible to address all feature attributes in the 2017 survey design, given the comprehensive nature of the attribute lists for each feature. The feature attributes were therefore rationalised according to JNCC priorities and available resources, resulting in a smaller subset.

The list of reporting sub-objectives for selected feature attributes (and supporting processes) of the designated features is presented in Table 1, alongside the analysis outputs generated for each.

1.3.4 What is not covered by this report

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

Table 1. Reporting sub-objectives addressed to achieve report Objective 1, for feature attributes of Wight-Barfleur Reef SAC (as defined in SACO for the Wight-Barfleur Reef SAC, JNCC 2018b).

Feature attributes (as defined by JNCC 2018b)	Outputs
Extent and distribution	
Extent	Maps of reef extent inside boxes with full MBES coverage. Validation of the Annex I Reef extent prediction for the full site, produced by Barrio-Froján *et al*. (2019) based on the One Arc Second Defra Marine DEM (Astrium 2011), using new acoustic and sample data.
Composition (particle size)	Proportion of reef (bedrock or stony) along camera tows, and stony reef coverage based on the reefiness assessment (Irving, 2009), cross-referenced to 2017 MBES data and the full site Annex I Reef layer (Barrio-Froján *et al*. 2019).
Distribution of biological assemblages	Maps of the spatial distribution of biotopes and assemblages.
Structure and function	
Fine scale topography	Reef elevation and coverage estimates from high definition (HD) video imagery for stony reef (Irving 2009). Description of fine scale topographic rugosity of the reef from camera altimeter data, linked with cross-sections comparing MBES bathymetry and altimeter data.
Characteristic communities	Description of biotopes observed in video and still images. Description of epifaunal communities encountered based on a biological community analysis of taxa observed in still images (including morphological Collaborative and Automated Tools for Analysis of Marine Imagery (CATAMI) approach).
Key and influential species	Key and influential taxa in epifaunal communities.
Habitat provision	Cover of reef-forming animals.
Supporting processes	
Hydrodynamic regime	Hydrodynamic model (tidal energy) – broad model for the overall site. Spatial trends observed in turbidity, salinity and temperature across the reef at the time of the survey.

2 Methods

2.1 Survey design

In April and May 2017, a survey was conducted at the Wight-Barfleur Reef SAC on-board the RV *Cefas Endeavour*. The survey collected Multibeam Echosounder (MBES) and Sidescan Sonar (SSS) data with associated drop-frame video and still image data.

The large size of the SAC, dearth of pre-existing MBES bathymetry coverage, and the need to target the designated feature led to a nested area survey approach. Survey effort was targeted in 6 rectangular areas of ~19 km^2 each (boxes A-F, Figure 4), to supplement the areas surveyed in 2013 (Figure 4). Each box was surveyed with full coverage of MBES and SSS (McIlwaine *et al.* 2020), except box F, which only has MBES coverage. SSS was not collected in box F due to survey time constraints. SSS was primarily collected to be used to identify potential patches of stony reef in paleochannels, which were not present in box F.

Areas of potential Annex I Reef to be targeted for sample data collection were identified based on an initial on-board interpretation of the acoustic data. The method used was adapted from that proposed by Verfaillie *et al.* (2009) to allow for restrictions in the data available. MBES bathymetry and backscatter, supplemented with a non-colinear subset of derivative topographic layers (slope, curvature, benthic position index, and roughness) were used to delineate areas of rocky substrate and potentially ecologically relevant zones within the reef. OBIA was performed using eCognition 9.2, to segment the acoustic coverage into image objects. Segmentation creates meaningful objects by identifying and placing boundaries around sections of the image with homogeneous characteristics across layers included in the segmentation. Segments with different acoustic and topographical attributes were clustered into groups, representing potential ecological zones, using K-means partitioning. The number of groups was determined through expert judgement with consideration of the Calinski-Harabasz algorithm for optimal number of groups (Calinski & Harabasz 1974). Drop-frame camera tow locations were selected to cover locations in each of the identified clusters, with additional survey stations placed over features determined to be of interest, based on the MBES or SSS data layers. A detailed description of the interpretation of acoustic data and placement of video tows is given in McIlwaine *et al.* (2020). A summary of acoustic and drop camera survey effort completed at the site is presented in Table 2 and shown in Figure 4.

Table 2. Summary of the acoustic coverage (rounded to the nearest km^2) and drop camera imagery collected during the Wight-Barfleur Reef SAC survey in 2017. Note that some stations have more than one video tow, resulting in more videos than drop camera stations.

	MBES and SSS coverage (km^2)	Number of drop camera stations sampled	Number of video tows (duration hh:mm)	Number of stills
Box A	19	13	13 (02:28)	277
Box B	19	13	14 (02:33)	264
Box C	20	13	13 (02:19)	241
Box D	19	15	15 (02:44)	311
Box E	21	14	15 (02:29)	241
Box F	18 (MBES only)	14	14 (02:55)	302
Total	**116**	**82**	**84 (15:28)**	**1,636**

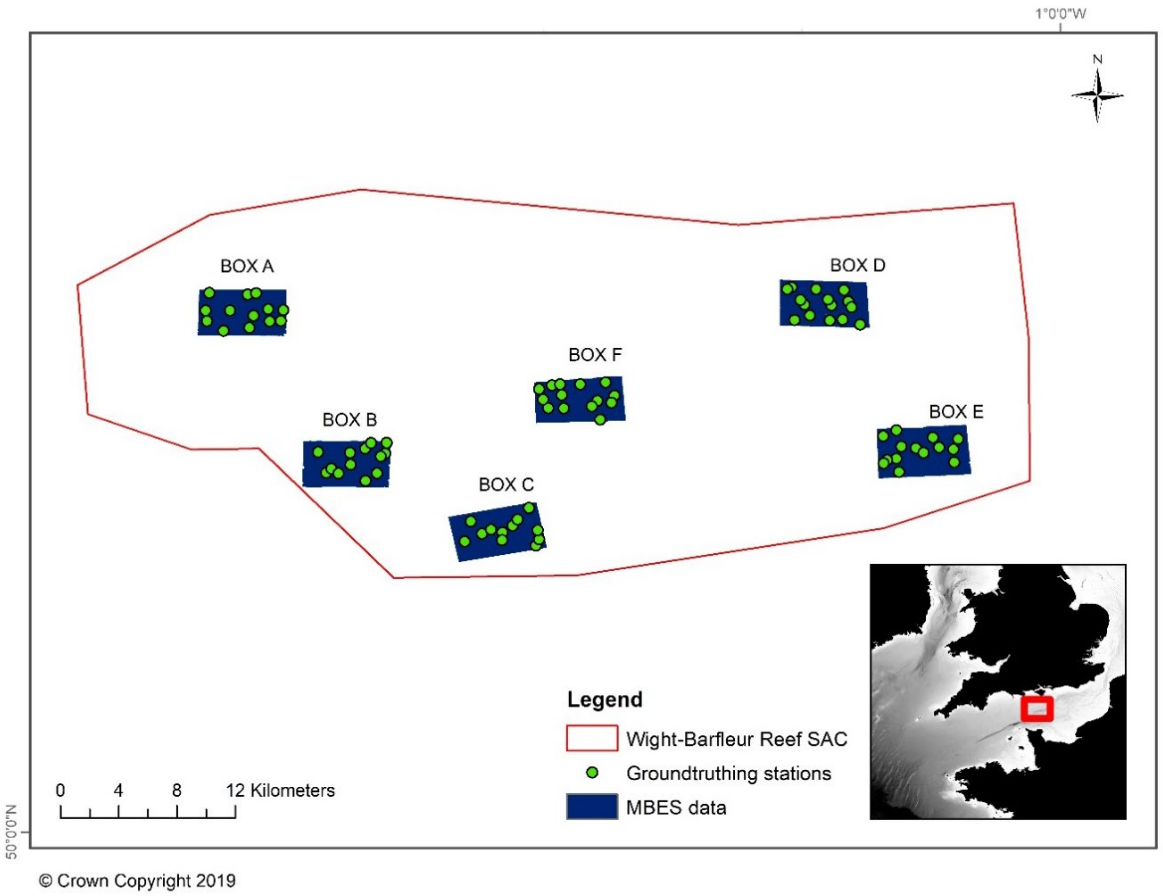

Figure 4. Location of drop camera tows collected at Wight-Barfleur Reef SAC in 2017.

2.2 Data acquisition and processing

2.2.1 Acoustic data

Acoustic data were collected simultaneously using a Kongsberg EM2040 multibeam echosounder (MBES) at 300 kHz and an Edgetech FS-4200 dual frequency (300/600 kHz) sidescan sonar (in combination with the Edgetech Discovery software for data recording). Survey lines were placed to achieve full coverage (minimum 30% overlap) with the MBES. Ship motion and position were recorded using the SBG Systems Motion Reference Unit (MRU) and CNAV 3050 high precision GPS. Bathymetry data were processed using CARIS HIPS and MBES backscatter data with the QPS FMGT software package. SSS data were recorded in XTF format and post-processed using the Triton Imaging software suite (Isis and TritonMap). Layback was applied using High Precision Acoustic Positioning (HiPAP). A more detailed description of the acoustic data collection is given in McIlwaine *et al.* (2020).

2.2.2 Seabed imagery

Seabed imagery data were acquired, processed and analysed to validate the extent and distribution of Annex I Reef and investigate the biological communities present (Objective 1) as well as assess the presence of OSPAR Threatened and/or Declining species or habitats (Objective 4) and non-indigenous species and marine litter (Objective 5).

Video and still imagery were acquired using a STR SeaSpyder “Telemetry” drop camera system with a 1080p HD video camera, 18-megapixel digital stills camera and scaling lasers spaced at 250 mm. Set-up and operation followed the Mapping European Seabed Habitats (MESH) ‘Recommended Operating Guidelines (ROG) for underwater video and photographic imaging techniques’ (Coggan *et al.* 2007). Video footage and digital still images were captured along predefined transects of approximately 100 m at 13-15 stations within each survey box. The minimum number of stations was chosen based on the results of a power analysis determining the number of samples required to detect 20% change in taxonomic richness with a power of 0.8, conducted on sample data previously collected at Wight-Barfleur SAC in 2013 (CEND0313, Barrio-Froján *et al.* 2019).

Speed over ground of the survey vessel was maintained at 0.3 knots for the duration of the tow. Position was recorded continuously at five second intervals throughout the tow, for both the side gantry steer point and the position derived from HiPAP.

Still images were captured at one-minute intervals, when a change in substratum occurred, and when appropriate to ensure availability of high-quality images for later epifauna identification. Each still image was geo-referenced to the nearest recorded position for the ship’s side gantry, from which the drop camera was deployed, by matching time stamps.

A more detailed description of the method and camera system used to collect imagery is given in McIlwaine *et al.* (2020).

2.2.3 Additional environmental data

The depth and altitude of the camera frame were measured with a 250 khz precision altimeter and logged once a second.

Salinity, chlorophyll-a, dissolved oxygen and turbidity were recorded along each video tow using a micrologger (Ecosystem Monitor 2; ESM2). Discrete water samples were collected using the continuous flow ‘ferrybox’ system for salinity, oxygen, suspended particulate matter (SPM) and chlorophyll-a to calibrate the ESM2 sensors. The drop camera frame was held at 4 m below sea level (level of the ‘ferrybox’ intake) for a few minutes whilst taking the water sample. The ESM2 logger and water sampling protocols are described in more detail in McIlwaine *et al.* (2020).

2.3 Data preparation and analysis

This section describes the preparation of datasets and analysis methodology used to produce each of the outputs listed under the sub-objectives listed in Table 1. The sub-sections are ordered, where possible, to follow the order in the table.

2.3.1 Extent and distribution – habitat maps

Acoustic data sources

Four different acoustic and bathymetric datasets were collated and utilised for producing the habitat maps in this report.

- **Defra (Astrium) DEM:** contains Defra's one arc second (~20 m cell size) Marine DEM for the waters surrounding the United Kingdom to a depth of 200 metres (Astrium 2011). Geographic coordinates were used throughout, and the DEM is referenced to the ETRS89 datum horizontally and Chart Datum vertically.

- **Pre-existing MBES dataset:** consists of compiled gridded bathymetry and backscatter (5 m cell size) collected in February 2012 and March 2013 (Barrio-Froján *et al*. 2019) merged with outputs from data collected in 2006 under a project mapping hard substrates in the central English Channel (ME1102, Coggan *et al*. 2009).

- **CEND0617 dataset:** consists of gridded MBES bathymetry and backscatter (2 m cell size) collected in six rectangular areas in June 2017 (Table 2).

- **UKHO HI1430 dataset:** contains additional MBES data in a peripheral area collected by UKHO in 2018 (HI1430). Resolution of 2 metre square per pixel.

Figure 5 shows the location of acoustic datasets from previous surveys (the “Pre-existing dataset", which includes 2006, 2012 and 2013 surveys) and the recent Cefas Endeavour CEND0617 survey and UKHO dataset.

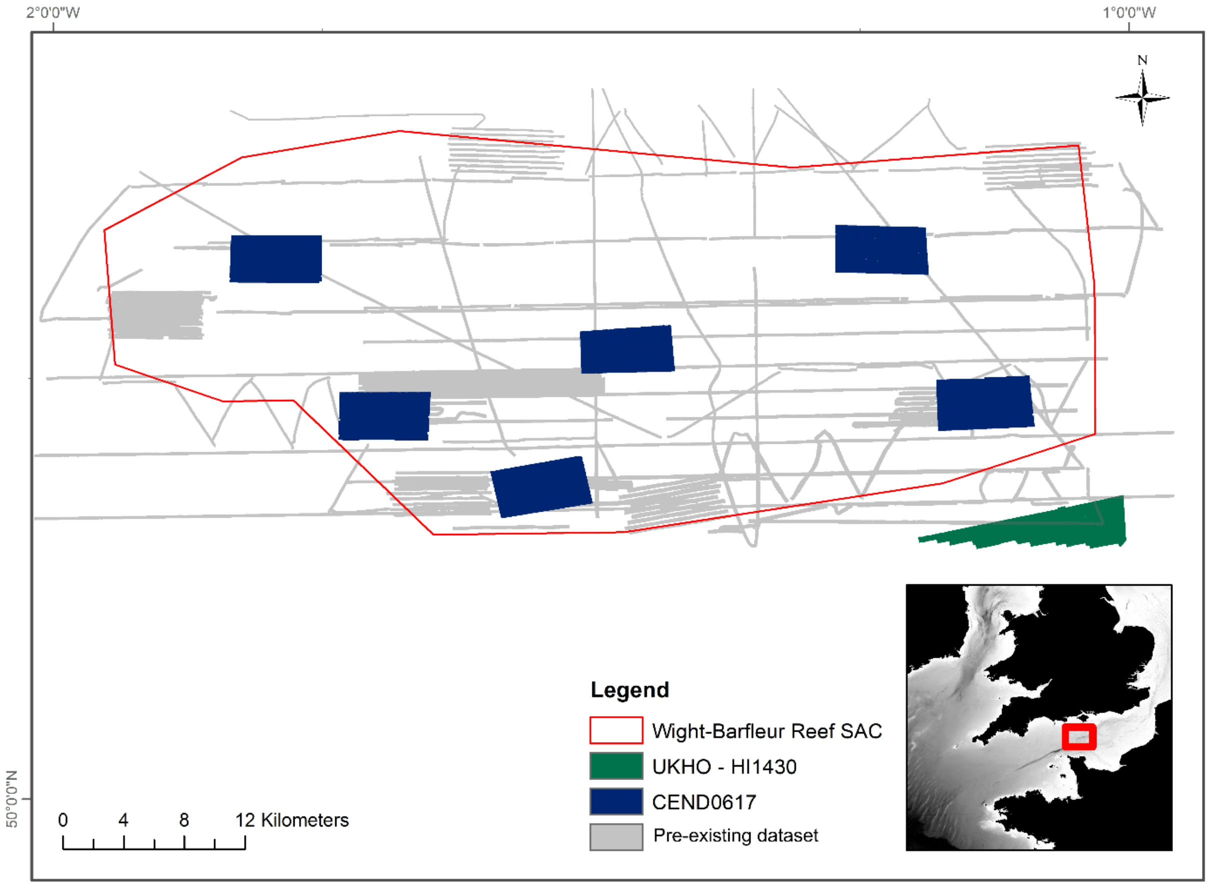

Figure 5. Acoustic data sources utilised in this report (Defra DEM not included as it covers the entire image area).

Object-based Image Analysis (OBIA)

A semi-automated approach (OBIA) was utilised to segment and classify the acoustic data based on the morphology and substrate type. The preliminary stage of the OBIA mapping approach consists in the creation of MBES derivatives (slope, Bathymetric Position Index (BPI), roughness, etc.) from the original layers (Table 3). The methodology for the segmentation and classification steps is described in detail in Appendix 5.

Table 3. Datasets used in this study and respective original resolution.

Layer	Pre-existing dataset	Original resolution		
		CEND0617 (2017)	UKHO HI1430	Defra/Astrium
MBES bathymetry	5 m	2 m	2 m	
MBES backscatter	5 m	1 m	1 m	
Defra one arc sec DEM				~120 m

Two morphological classes, that indicate the 3D variation at seabed, and three sedimentological subclasses, that indicate the grain size variation of the substratum, were considered appropriate for mapping: Ridges and Planes.

Ridges were defined as elongated rock or sediment crests, of variable length, > 30-40 m wide, > 2–3 m high, indicating slopes of at least 3–5°. Rock outcrops, channel and plateau sides and current-induced mobile sediment landforms all fall within this category. Plane categories included the remaining portions of the MBES data, including plateaus, channels and platforms (also gently sloping). Grain size subclasses were defined as follows:

- rock: includes bedrock to small boulders;
- boulders to pebbles: from small boulders to coarse pebbles;
- gravel to sand: from coarse pebbles to sand.

This coarse subdivision permitted the classification (without the risk of overinterpretation of the data) of the substrate into:

- Potential Annex I Reef morphologies: bedrock ridges and planes and boulders to pebbles ridges and planes.
- Not Annex I Reef morphologies: gravel to sand ridges and planes.

The boundaries between adjacent sedimentological classes (i.e. rock with coarse and coarse with fine) must be considered relatively fluid, as a high degree of mixing is observed in the sample data.

A complex set of classification rules was adopted in this study after a statistical analysis of a training set of segmented objects (see Appendix 5). Following this procedure, the results produced classes corresponding well with the areas where the geomorphic type has been identified from visual inspection of the MBES data. A few manual modifications to perfect the classification, guided by expert judgement, were carried out after the automated process. The results of the analysis are presented in Section 3.1 and discussed in Section 4.1.

Validation of the full site Annex I Reef extent map

Annex I Reef extent obtained from the Defra DEM was plotted together and compared to the results from the OBIA analysis. Due to the greater resolution of the 2017 bathymetry, a quantitative comparison was not possible and a correspondence between the two maps was established on a qualitative basis. The results are presented and discussed in Section 4.1.

2.3.2 Extent and distribution – composition of substrata

Composition of the substratum (i.e. stony reef, bedrock reef or no reef) was obtained from video segments by the imagery analyst. Results were plotted against the OBIA maps to corroborate the object-based classification and show the spatial distribution of the substrate types. The results are shown in Section 3.3.1 and discussed in Section 4.1.

2.3.3 Extent and distribution – biotopes and biological assemblages

The spatial distribution of biotopes, as assigned to video segments by the imagery analyst was investigated. Biotope maps were not produced as it was only possible to identify EUNIS Level 3 habitats from the video data (see Section 2.3.2). The assemblage groups resulting from multivariate community analysis were mapped across the site and the results are presented in Section 2.3.3.

2.3.4 Structure and function – fine scale topography

Whilst MBES data was useful for identifying the general reef extent and distribution at the scale of tens of metres, a finer scale approach was required to investigate the physical structure of the reef itself. A combined approach utilised the reef types and fine scale structure observed in video segments and the bathymetric profiles across video tows derived from the camera-mounted altitude and depth sensors to achieve a resolution of 10 cm to 1 m.

Reef composition in video segments

The video segment dataset was used to tabulate the frequency of the reef elevation and complexity classes given in Table 4 for stony reef. For this purpose, only those segments with a North-East Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) quality category of 'Good' or 'Excellent' were included, to ensure consistent estimates of category. This subset includes 1,426 of the total 1,536 segments (Table 5).

Morphological analysis of camera altitude profiles

Camera altitude profiles were analysed to extract meaningful topological parameters that could inform the discrimination of different video segments and be linked to distribution of reef communities. Roughness, waviness and boulder parameters were calculated using Python.

The roughness of a profile is represented by the fine irregularities (depth differences in this case) between adjacent sample points. Having calculated that each profile sample point is approximately 20 cm apart, the roughness value should pick up objects from 20 cm to 1 m in length. Two variables were obtained:

- **Ra** = the arithmetical mean deviation of the assessed profile from an averaged baseline (averaged profile)

$$(1) \qquad Ra = \frac{1}{n}\sum_{i=1}^{n}(|y_i| - |\bar{y}|)\ (1)$$

where *y* is the altitude measured at a sample point *i*, $\bar{y}$ is the average of the profile and *n* is the number of sample points.

- **Rms** = Root mean squared of the profile

$$(2) \qquad Rms = \sqrt{\frac{1}{n}\sum_{i=1}^{n} y_i^2}$$

A Savitzky-Golay filter (Savitzky & Golay 1964) was used for the purpose of smoothing the data and isolating the roughness from the general profile trend (and obtain a baseline). The filter uses convolution, by fitting successive sub-sets of adjacent data points with a low-degree polynomial by the method of linear least squares. A window of 15 data points (~3 m) and a 3rd grade polynomial was applied, which seemed to give the best results. Similar parameters to the previous (**Wa** (1) and **Wms** (2)) were calculated on the filtered profile to quantify the general "waviness" of the profile, which gives an indication of broad scale irregularity (e.g. larger terrain structures, such as bedrock ridges).

An attempt to identify boulders on the profile was also made. This includes only large boulders protruding from the seabed, (from 25 cm to 3 m high and from 60 cm to 5 m wide) using peak finding functions in the Python Scipy Signal package to identify peaks of a certain size and width. The number of identified boulders and their prominence (in m) is given for each profile.

The results were compared to substrate type as described from video tow analysis reclassed as bedrock, boulders (from 50 cm up), cobble-pebbles (from 6.4 cm to 50 cm), and fines (below 6 cm).

2.3.5 Structure and function – characteristic communities

Epifaunal data preparation

Video and still imagery were processed and subjected to external quality assurance following the NMBAQC guidelines (Turner *et al.* 2016).

Each video transect was initially split into segments determined by change in habitat and the presence of stony or bedrock reef. Reef segments were subsequently split into 5 m sub-segments for further analysis. In total data were divided into 363 segments with these segments further divided into 1,537 sub-segments (Figure 6).

The Field of View (FOV, m^2) for each still image was calculated using the horizontal separation of the laser scale dots based on the method developed from Wakefield and Genin (1987). Gardline's CountEM software was used to automatically detect the location of the laser dots within the image and these measurements were then used, along with camera view angles, to produce an approximate area (Gardline 2017).

Percentage cover of reef substrata, an estimate of reef height and faunal coverage were also estimated for each sub-segment of stony reef, in accordance with Irving (2009). Categories used for percentage cover, height and faunal coverage are shown in Table 4. Each video sub-segment and still image was assigned both a EUNIS and a Marine Habitat Classification of Britain & Ireland habitat classification, in accordance with the JNCC biotope guidance (Parry 2015). Individuals present in video segments and still images were identified to the lowest possible taxonomic level. Abundance of each observed taxon was recorded using the SACFOR scale and either percentage cover or individual count, as appropriate.

Table 4. Categories used to classify cover of stony reef substrata, reef height and fauna cover in video segments (after Irving 2009).

Cover of hard substrata	Reef height	Fauna coverage
Not a stony reef (< 10%)	Flat seabed	Low–Medium (< 80% epifauna)
Low (10–40%)	Low (< 64 mm)	High (> 80% epifauna)
Medium (40–95%)	Medium (64 mm–5 m)	
High (> 95%)	High (> 5 m)	

Still images collected along a transect each cover less than 1 m^2 of seabed (0.2–0.7 m^2 for a good quality image). To achieve a representative sample, the sampling unit is set at the level of the transect. In an ideal situation, analysis would be based on a standardised set of samples, each consisting of the same number of images, acquired at the same altitude (and consequently each representing the same area of seabed) covering the same distance of tow over a continuous patch of a single habitat at each sampling location. In practice, this is often unfeasible.

In this study, a subset of the full still image dataset was used to prepare a semi-standardised set of images covering a roughly equal area per sample for use in community and diversity analyses. The topographic variability of the reef leads to high variability in slope and depth, as well as transitions between bedrock reef, stony reef and coarse sediment along the camera tow. Hence, the sampling unit was confined within the video segments determined by analysts as stretches of the same habitat type (Figure 6). Although it is possible that using in this definition one video tow has more than one segment representing the same habitat type, they will not be consecutive and will be interspersed by segments of other habitat types.

The subset of images forming each sample was randomly selected from images meeting the minimum standards of a FOV no larger than 0.6 m^2 and ‘Good’ or ‘Excellent’ image quality (as defined in the NMBAQC guidelines, Turner *et al*. 2016). The FOV threshold used was chosen to optimise the number of images, sample stations and taxa to be retained for further analyses, whilst maintaining sufficient image quality and ground resolution to identify taxa with reasonable taxonomic detail. The number of images (and range for the required seabed surface area) making up the sample (randomly selected image subset) was decided based on species accumulation curves (see Appendix 2) computed using all images meeting the FOV and quality requirements. With the limitations on number of available images, there was a trade-off between the desired area of seabed for a representative sample and the number of samples in which this area was attainable. Consequently, the sampling unit for still images was defined as a group of photos covering an area between 1– 2 m^2 collected within a continuous video segment. For brevity, the sampling unit is referred as a transect for the remainder of the report. The process is described in detail in Appendix 2.

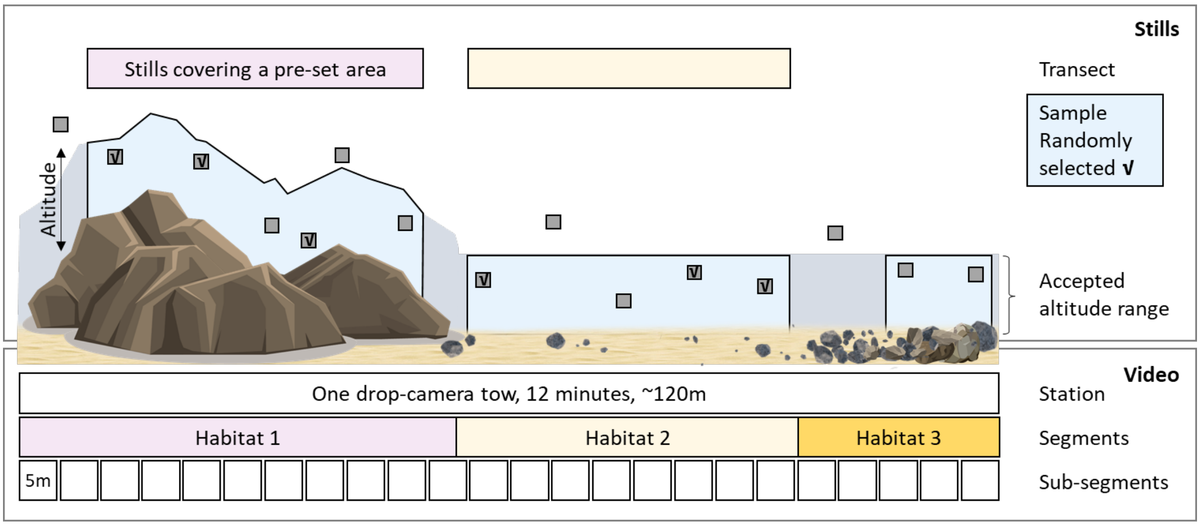

Figure 6. Schematic explaining the units of analysis used for video (segments and sub-segments) and still imagery (a randomly selected sample of images in each habitat with sufficient number of images within an accepted altitude range).

The sub-selection resulted in a dataset comprising 227 comparable quality images of rock habitat from 43 video segments, each containing a variable number of aggregated images equating to an area of 1–2 m^2. The number of stills per transect used was five in most cases, ranging up to seven depending on how many stills were required to make up the standard sample area (Table 5).

Table 5. Video segment and still image data from 2017 survey of Wight-Barfleur SAC used in this report.

	Full dataset	Good NMBAQC / Fauna (video)	Semi-standardised dataset (images)
Stations	82	82	36
Video segments (habitat)	361	280	43
Video sub-segments (5 m)	1536	1,426 / 238	N/A
Images	1490	929	227
Images / segment ($\bar{x}$ ± sd)	4.7 (5.1)	3.3 (3.2)	5.3 (0.5)
Data used	Habitat mapping	Categorical analysis / total epifauna coverage	Community analysis, Taxon richness

Taxa in the images were identified to varying levels of detail, depending on image quality and resolution, as well as the visibility of individuals in the image; therefore, the taxon list was truncated in two ways (see Appendix 3).

Firstly, to include the maximum number of separate morphologically distinct groups of individuals a list of morphotypes/taxa was used to avoid grouping taxon entries at high taxonomic levels. This approach allows more information to be retained in the community matrix than truncation up the taxonomic tree to lowest common denominator, but it maintains the mixed multilevel taxonomic identification structure and places high weight on certain easily distinguishable taxa.

A second version of the datasets used a modified version of the CATAMI classification scheme of standardised terminology for annotating benthic substrates and biota in marine imagery (Althaus *et al*. 2015). Taxa were truncated to the lowest level of the CATAMI scheme to achieve consistent identification of morphologically explicit categories, more akin to a reliable identification of taxa to one taxonomic level. This approach allows comparison between locations and timepoints within a limited number of available taxon labels, applied each time, making data collation repeatable and lists comparable. The approach reduces the noise inherent in taxon matrices comprising multiple levels of taxonomic hierarchy, for use in subsequent community analyses. It also enables the application of a restricted set of possible taxa for use in repeatable diversity estimates.

Percent cover was aggregated as a mean across the images in the sample, whilst counts were expressed as a density (individuals/m^2) by dividing the total number observed in the images comprising each sample by its total FOV.

The full imagery datasets (not a subset) were analysed for the presence of marine litter (Objective 5; see Appendix 4 for MSFD categories) and non-indigenous species (Objective 5; see Appendix 5 for list).

Environmental variables linked to video sub-segments and still images

All univariate and multivariate statistical analyses of the 5 m video sub-segments and still images utilised the same set of environmental variables. Depth, backscatter and the values of topographic bathymetric derivatives were extracted from the results of the OBIA segmentation carried out on the MBES data layers (see Section 2.3.1 and Appendix 6). Each video sub-segment was associated with the mean value from intersecting objects for depth, backscatter, slope height, normalised height, Terrain Roughness Index (TRI) and three BPI layers calculated with neighbourhoods of 25, 10 and 5 cells. The percentage cover of substrate categories (including bedrock, boulders, cobbles, pebbles, gravel, shell, sand and mud) were derived from the analysis of video sub-segments. Cobbles and pebbles were combined into one variable and all soft sediment was pooled into one variable (fines). Additionally, bedrock, boulders, cobbles and pebbles were combined to represent the percentage cover of available attachment surface for sessile organisms (hard substrata). Further, each segment was assigned its corresponding Profile Roughness (Ra/Rms) and Profile Waviness (Wa/Wms, see above).

Water quality parameters from the ESM2-logger were not included as variation across the site was low.

Each still image was related to its corresponding video segment and sub-segment and assigned the associated environmental variable attributes.

Characterising epifauna and communities in still images

Multivariate analyses of epifaunal data were conducted to investigate the structure and composition of characteristic communities. The truncated epifaunal community data were imported into PRIMER v6 to allow multivariate analysis, in combination with associated environmental parameters. The total number of taxa at each transect was established. Faunal matrices with percent cover and densities were standardised to the fraction of the species total. A preliminary analysis comparing results obtained using the morphospecies and CATAMI datasets with percent cover and densities, determined that using the morphospecies dataset did not add any essential information to analysis over the CATAMI dataset. Consequently, a dataset combining the standardised values for all CATAMI taxa was selected for further analysis.

ANOSIM was used to investigate difference between the Annex I Reef types (‘Not reef’, ‘Stony reef’ and ‘Bedrock reef’).

Non-metric multidimensional scaling (nMDS) ordination plots of Bray-Curtis similarity, and hierarchical cluster analysis using the Similarity Profile (SIMPROF) test on the standardised abundance data (% cover and density as fraction of taxon total), were used to identify community grouping within the site. The Similarity Percentages (SIMPER) routine was used to identify the taxa contributing the most to similarities within and differences between the cluster groups (Clarke *et al.* 2014).

The full list of environmental parameters collected for each transect was reduced by removing BPI 10 and BPI 5 and MBES backscatter, which were all highly correlated with other variables. The environmental variables with the greatest correlation to patterns in the community composition were established using the BEST routine in PRIMER v6 (Clarke *et al*. 2014).

2.3.6 Structure and function – key and influential species

Indicator value analysis

Indicator value analysis (IndVal; Dufrěne & Legendre 1997) implemented in R package *labdsv* (Roberts 2016) was used to evaluate the strength and exclusivity of association of taxa with the cluster groups. Indicator value analysis contrasts a taxon’s group prominence (how abundant a taxon is within a group) with its group fidelity (how frequently a taxon is observed in a group). The analysis outputs each taxon’s frequency, abundance and the derived indicator value in each group. Significance of the indicator value for each taxon for the group it is most strongly associated with is evaluated through a permutation test. High indicator species values can suggest key taxa, specific to a community group, for future monitoring.

Evaluating potential indicators

Where potential indicators were identified for future monitoring of feature condition within the site (e.g. a metric, or a specific taxon or group of taxa), they were evaluated against the criteria provided in Table 6. These criteria were set out by OSPAR (2012) in advice on the selection of indicators for descriptors of marine biodiversity under the MSFD, but in this report they are used to evaluate potential site or feature specific indicators.

Table 6. OSPAR (2012) state indicator selection criteria (adapted from ICES and UK scientific indicator evaluation).

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

2.3.7 Structure and function – habitat provision

Epifauna coverage in video segments

Epifauna coverage across sampling locations and reef types was investigated to address the habitat provision sub-objective. Epifauna covering the rocky reef provide additional three-dimensional structure from micro to macro scales, adding to diversity and food resources for many associated mobile fauna. Assessment of coverage from video is very subjective and it is difficult to achieve the required repeatability for robust monitoring. Hence, the investigation into epifauna coverage here is preliminary and aims to elucidate patterns related to environmental conditions, in order to facilitate planning of future monitoring of habitat provision. The analysis uses the 5 m video sub-segments, 238 of which were of consistent enough quality to enumerate benthic fauna (Table 5). The mean and range of total percentage cover of fauna was calculated from the sum of all fauna recorded as percent coverage in each segment. The relationship between fauna coverage and the associated environmental variable attributes was investigated using Generalised Additive Models (GAM) because of the non-linear relationships observed for many of the variables (Wood 2017). The models were fitted in R (version 3.4.3; R Core Team 2017) using the penalised thin plate regression splines in the *mgcv* package (version 1.8-28; Wood 2017). The shrinking thin plate splines were used, with degrees of freedom restricted to a maximum of three to avoid overfitting. Variable selection for the model was done by adding variables in the order of their deviance explained in a single variable model. Variables highly correlated (> 0.6) with another variable already in the model were not included.

2.3.8 Supporting processes

Tidal model

A tidal model was used to present information relating to the supporting processes which are known to influence the Annex I Reef within the SAC (Objective 6). Peak flood and ebb tidal current velocities (ms^{-1}) were generated using model output downloaded from the E.U. Copernicus Marine Service ocean physics analysis and forecast for the North-West European Shelf data product (northwestshelf_analysis_forecast_phy_004_013). Currents were extracted at the 15 m depth level and are representative of mid-depth values. Results shown are the maximum flood (eastward directed) and ebb (westwards directed) values over a 15-day spring -neap cycle.

Additional environmental data

The ESM-logger data on salinity, chlorophyll, dissolved oxygen and turbidity collected along each video tow were extracted from the log files and the peak flood and ebb velocities were generated using model output downloaded from the E.U. Copernicus Marine Service Information (https://www.copernicus.eu/en/services/marine) data product northwestshelf_analysis_forecast_phy_004_013. Currents were extracted at the 15 m depth level and are representative of mid-depth values. Results shown are the maximum flood (eastward directed) and ebb (westwards directed) values over a 15-day spring -neap cycle. range of values within each tow investigated. After determining that variability was low over the distance of a camera tow, the mean was calculated for each station.

2.3.9 OSPAR Threatened and/or Declining Habitats and Species and Non-indigenous species (NIS)

The epifaunal taxon list generated from the seabed imagery data was cross-referenced against lists of OSPAR Threatened and/or Declining Habitats and Species and non-indigenous target species which have been selected for assessment of Good Environmental Status in GB waters under MSFD Descriptor 2 and identified as significant by the GB Non-Native Species Secretariat. These lists can be found in Appendix 5.

3 Results

3.1 Physical and environmental overview

The distribution of Annex I Reef features in the SAC is determined by the geological structure at the site. Bedrock structure and lithology, which is shown in Figure 7, strongly influence the presence/absence of reef prone features (e.g. boulder/cobbles pavements or bedrock ridges) and can be used to predict distribution in unmapped areas.

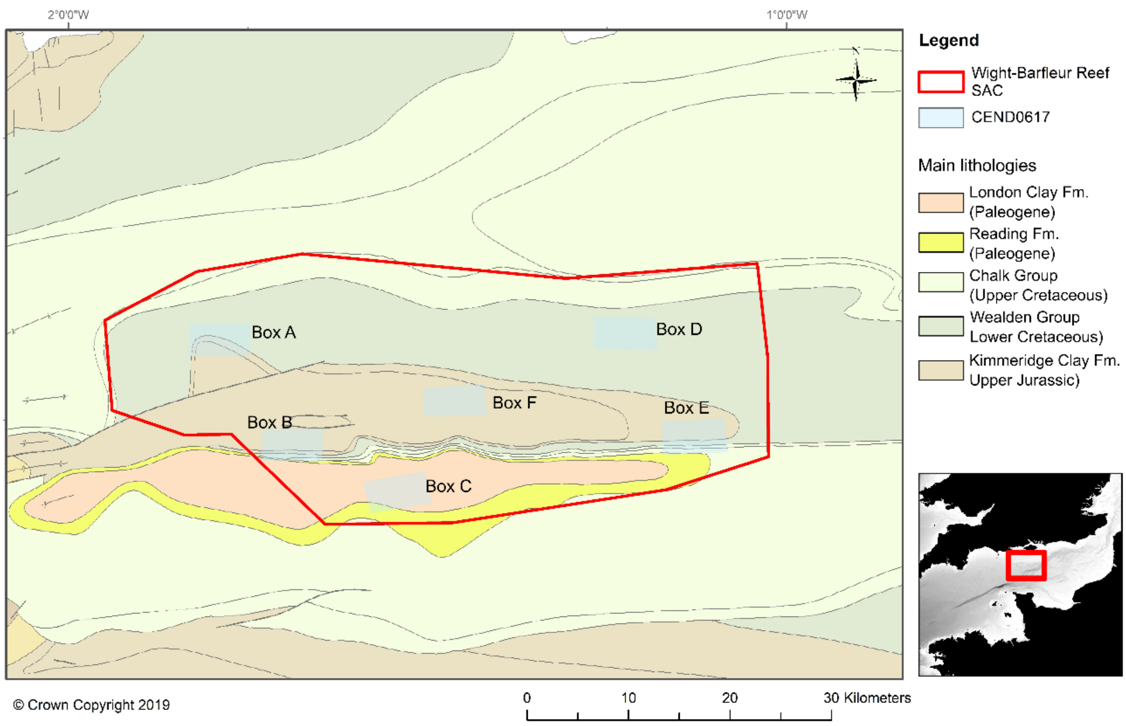

Figure 7. Geological and structural overview of Wight-Barfleur SAC (from BGS 500:000 offshore geology) relative to the location of the six CEND0617 boxes.

To the north the geology is dominated by Cretaceous mudstones (box D), that display very rugged and irregular bedrock ridges. The centre of the SAC is occupied by the Jurassic Kimmeridge Clay Formation. They crop out in box A, B, F, E, where the different hardness of stratified layers (beds) has caused the formation of a series of crests and troughs. In box F the ridge pattern is regular, with short peaks and flat, inclined planes. The peaks are in few cases up to 5 m high, but generally on the order of 1–3 m. The planes extend for tens of metres (up to 100 m). Finally, box C is mainly occupied by Paleogene clays (London Clay Fm.)

The seabed of Wight-Barfleur SAC is characterised by exposed bedrock or bedrock covered by a thin (below 1 m) veneer of sediment (cf. James *et al*. 2011). No significant thicknesses (up to 30 m) of sediment are present even in infilled portions of palaeovalleys (James *et al*. 2011), but a small number of constructional bedforms, i.e. sandwaves, dunes and megaripples are observed in box A, B, D and F. These correspond to the “Ridge – gravel to sand” class. Sediments are dominated by gravel and abundant cobbles and boulders (Mellet *et al*. 2013), with limited sand and virtually no mud. This suggests a high energy regime (cf. Barrio-Froján *et al*. 2019), where bottom currents affect the stability and movement of loose sediment, from cobbles to sand.

3.2 Extent and distribution of stony and bedrock Annex I Reef

Results from the OBIA mapping, fine scale topographical analysis of camera tow profiles, reef observations from images and video segments and information on reef distribution gathered during previous surveys (Barrio-Froján *et al*. 2019) were all combined to describe the extent and distribution of Annex I Reef. It is apparent that Annex I Reef habitat is present throughout most of the survey area, interspersed with pockets of sediment veneer and exposed flat bedrock.

In the previous report (Barrio-Froján *et al*. 2019) the discrimination of the four categories of Annex I Reef (i.e. bedrock reef, biogenic reef, stony reef, not reef) based on the analysis of the extracted object attributes of MBES, and derivative data was not attempted as it was deemed unfeasible. In most cases there is a significant overlap of value ranges for the different reef categories. For example, a high degree of impurity is observed in the backscatter value distribution (Figure 8), which means that a reliable distinction between the different reef categories is not possible.

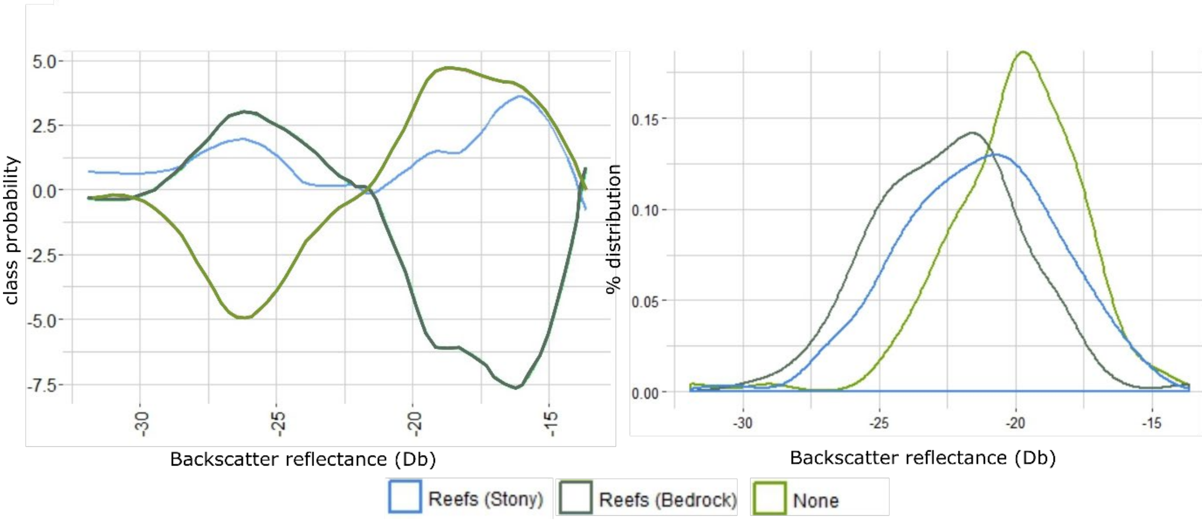

Figure 8. Left: effect of backscatter variable on probability of an object to belong to one of the three Annex I Reef classes. Right: distribution plots of backscatter values, notice the high overlap between classes.

Annex I Reef could be linked to both ridges and planes presented in the habitat maps, with the maps broadly discriminating between reef prone (e.g. bedrock and boulders to pebbles ridges) vs. not prone (e.g. gravel to sand ridges and planes) areas. Moreover, this habitat map improves on the previous study as:

1) ridges (boulders to pebbles and bedrock) could be linked to Annex I Reefs with a vertical expression observable on acoustic data;
2) a “mixed” sediment response (called mosaic in the previous report, cf. Barrio-Froján *et al*. 2019) mostly corresponds to “Plane – boulders to pebbles”. This class better isolates this signal from other more distinguishable classes;
3) it provides a high-detail morphological classification of the seabed, which entails a better description than manual delineation from sidescan sonar;
4) it can be used to better inform future monitoring.

Distinctive acoustic signatures present on the MBES data include complex morphologies and backscatter patches of high and low intensity returns. Backscatter returns are not uniform throughout the Wight-Barfleur Reef SAC, indicating a heterogeneous seabed dominated by rocky and stony reef.

The overview of the OBIA results for both CEND0617 and pre-existing datasets is presented in Figure 9 and Figure 10. The data acquired from each intensely surveyed box is considered in detail below.

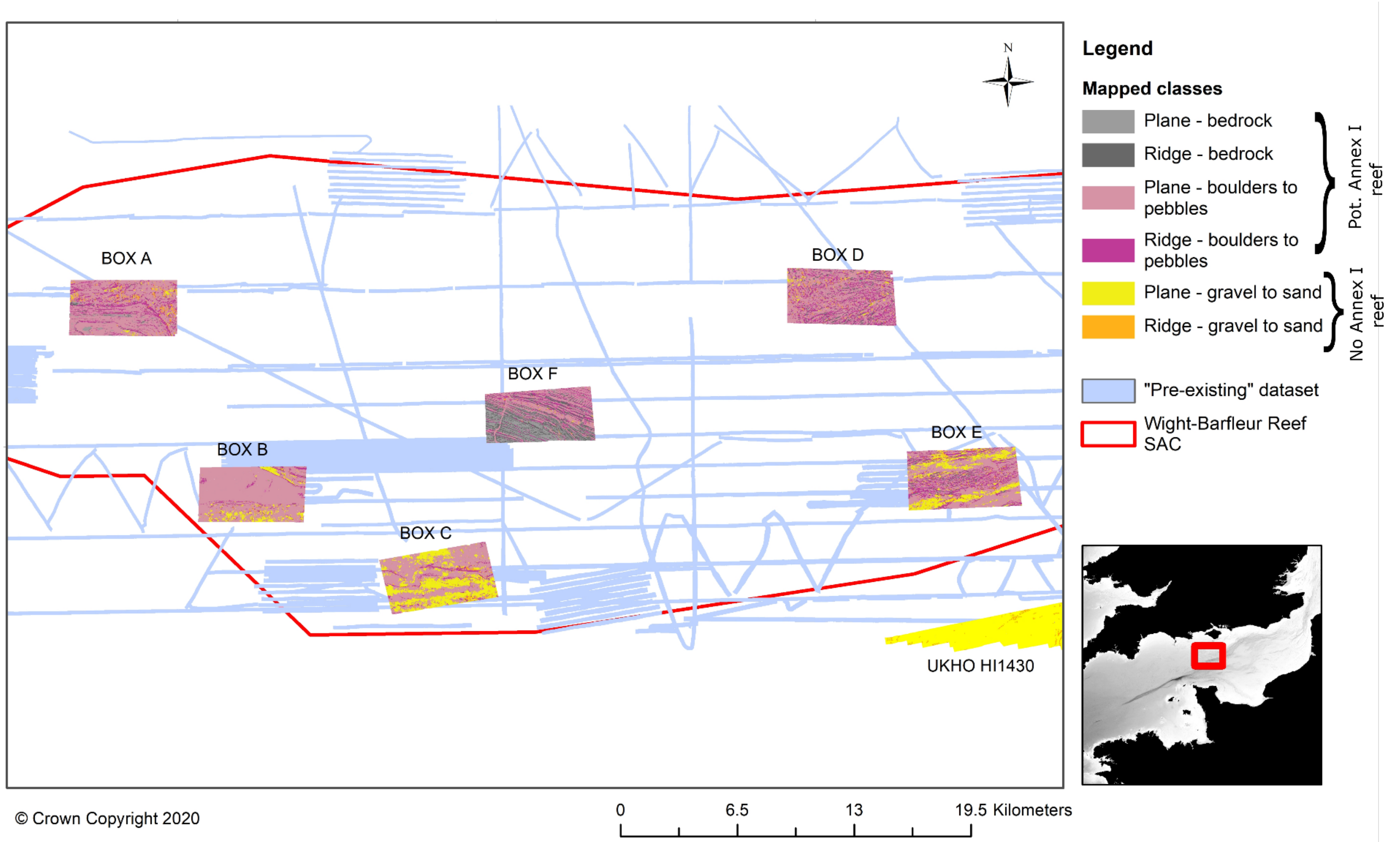

Figure 9. Results from the OBIA of the 2017 and UKHO HI1430 data. Note the potential vs no Annex I Reef classes.

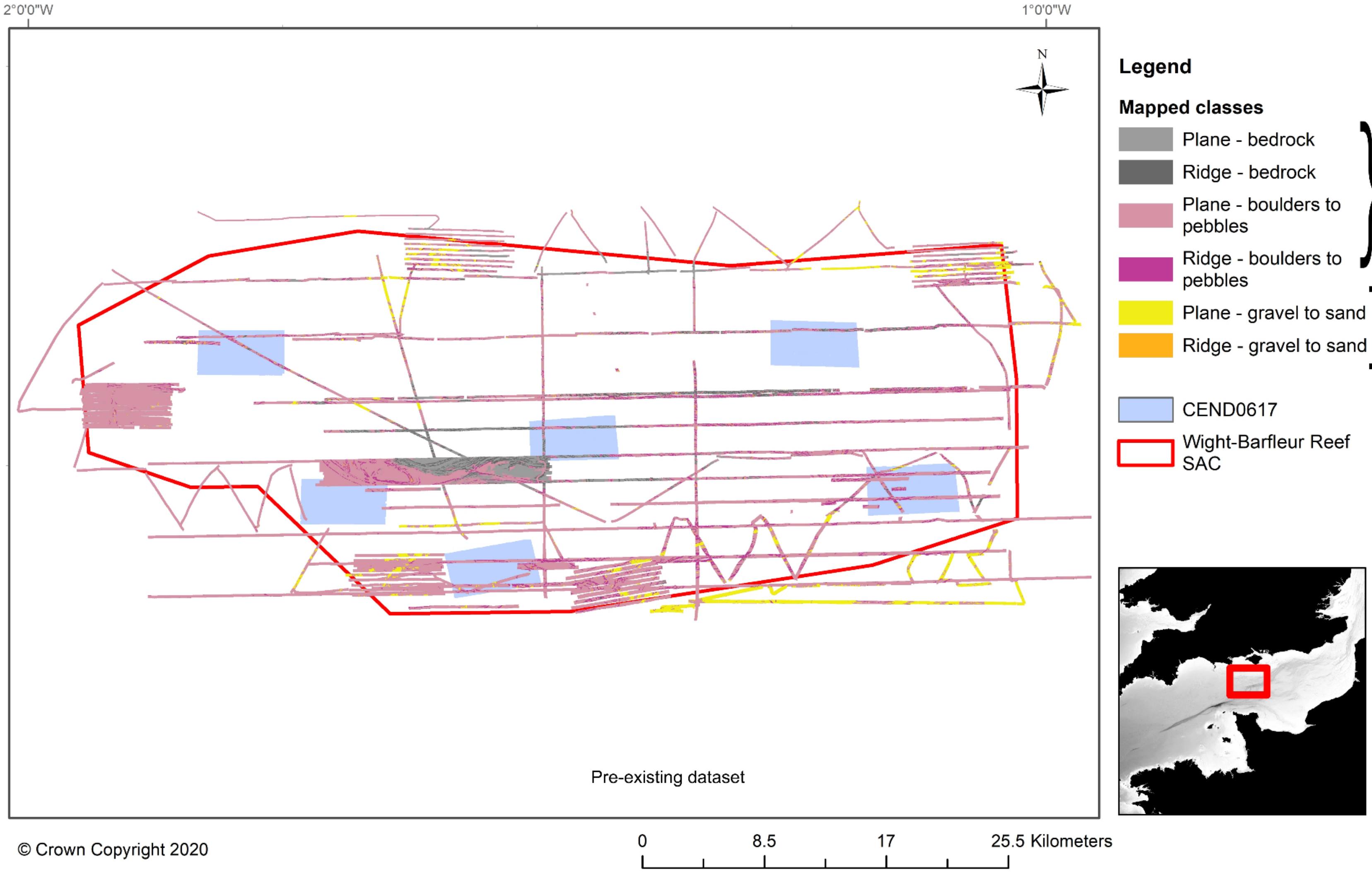

Figure 10. Results from the OBIA of the pre-existing dataset. Note the potential vs no Annex I Reef classes.

Box A

Acoustic data from box A revealed a seabed platform characterised by a series of closely spaced folded longitudinal ridges in the southern half of the area. Sparse patches of exposed bedrock often correspond to ridge crests, but boulder to cobble sediments cover the greater part of the area, both on ridges and depressions. Megaripple trains have been observed on flat seabed between ridges and indicate presence of finer (sandy to gravelly) sediment. Bedrock and mostly stony reefs have been observed on all the video tows, therefore it is highly likely that they cover the entire area apart from the sand megaripples (mapped as “plane – gravel to sand”, Figure 11).

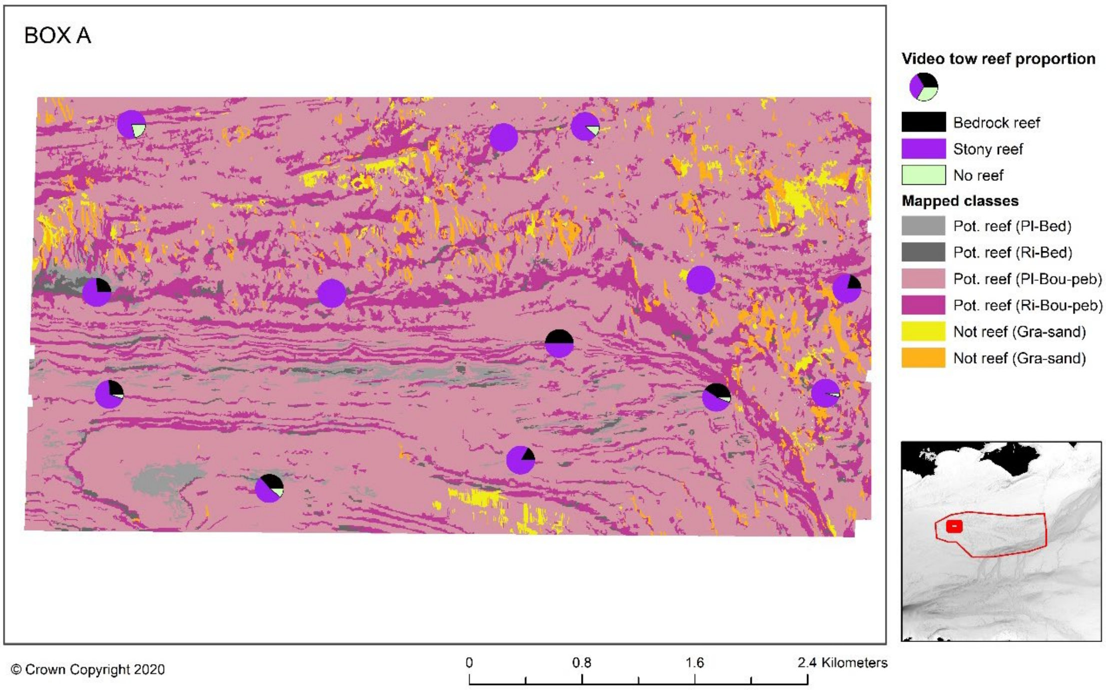

Figure 11. OBIA classification and video tow total Annex I Reef proportions for Box A.

The northern section of the box is characterised by an E–W oriented channel-like depression, up to 10 m deeper than the surrounding seabed, occupied by a series of sandwaves. No drop camera stations were collected in the channel, but it is likely mainly occupied by coarse to fine unstable sediment. North and east of the channel the seabed is again occupied by a mosaic of bedrock and mainly boulders to pebbles sediment, often related to topographic features (ridges or knolls) at seabed. Annex I stony reefs were observed on all tows, suggesting its widespread occurrence and the presence of a veneer of cobbles to coarse sediment covering both Planes and Ridges.

Box B

A flat plateau-like feature at 53–54 m water depth and gently sloping to the north-west occupies the greater (centre and northern) part of the box. The plateau is devoid of major bathymetric features, apart from subtle curvilinear ridges in the central part, and a 500 m wide, ~8 m deep channel to the north-west. The southern boundary of the plateau represents an area of rocks and sediment. The southern area and the channel appear to be occupied by mobile fine sediment. The gravel to sandy sediment is probably only a very thin veneer, as backscatter and video data point to a predominance of very coarse material (pebbles to boulders), which covers the entire area.

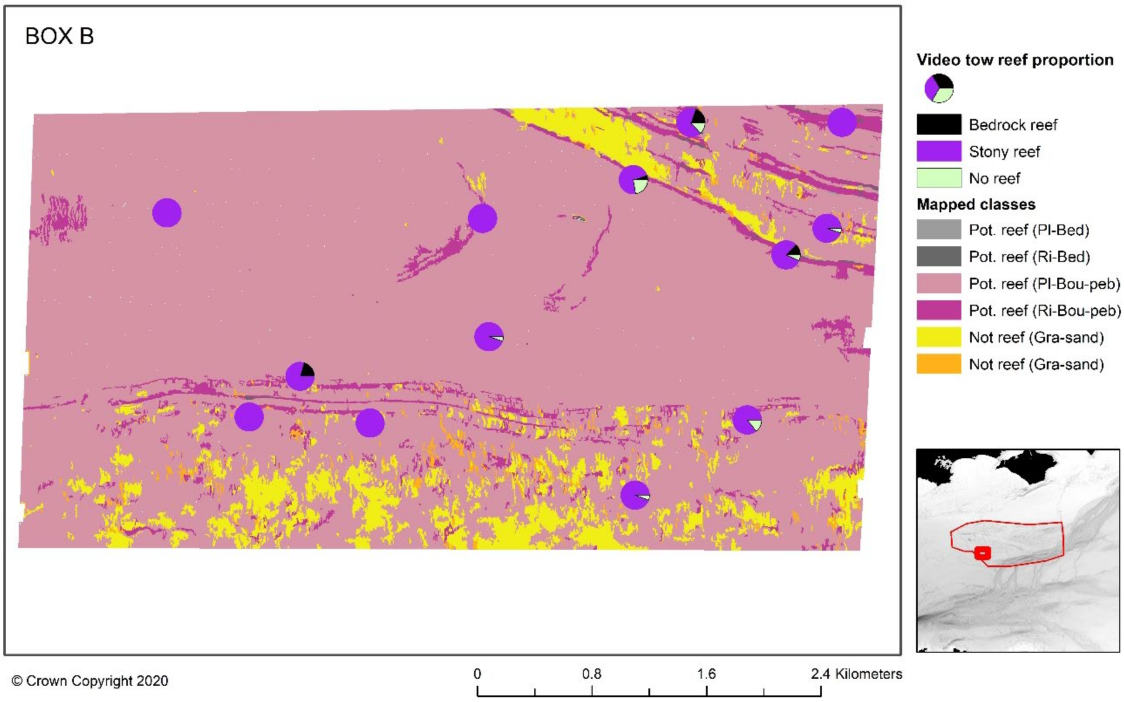

Figure 12. OBIA classification and video tow total Annex I Reef proportions for Box B.

Annex I stony reef is observed in all the video tows and is probably distributed evenly across the box (Figure 12), apart from the areas of fine sediment and megaripple cover. It is likely however, that the fine sediment cover is only transient.

Box C

Acoustic data show a flat and smooth seabed signal in the northern part of the box, with small circular holes, between 7 m and 12 m in diameter and 0.5–1 m deep that could be pockmarks, indicating a relatively thick gravel to sand cover. Video tow data confirmed the abundance of fine material in the area, with a superficial layer of pebbles and cobbles acting as a substrate for biological communities. A higher percentage of “no reef” sections is observed on the video tows from this area (Figure 13). The southern part of the box presents irregular ridges and knolls separated by broad planes and depressions which are occupied by fine mobile sediments. All ridges appear to be associated with reef presence, whilst video tows corresponding to “plane – gravel to sand” objects present significantly less recognised Annex I Reef.

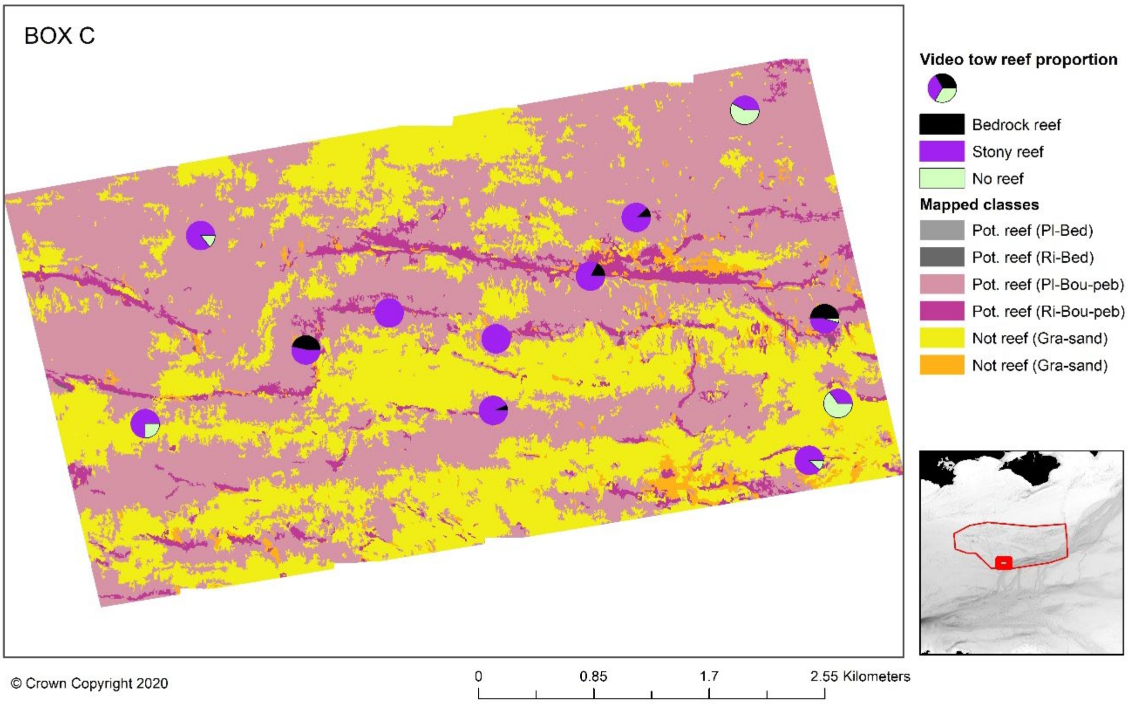

Figure 13. OBIA classification and video tow total Annex I Reef proportions for Box C.

Box D

The bathymetry in this box is highly irregular. Loose coarse sediment appears to cover the entire area, leaving very few and isolated bedrock outcrops exposed. Annex I Reef (mostly stony) is described in almost all the occurrence of video tows crossing or sweeping along a ridge feature. In between the crests the seabed is covered by a mixture of mainly coarse and some fine sediments. No reef was observed in several locations corresponding to “Plane – boulders to pebbles”, suggesting either a high proportion of sand or high energy environment causing instability and sediment movement. This hypothesis is corroborated by the abundance of sandwaves and megaripples scattered across the entire box, travelling from east to west across the area (Figure 14).

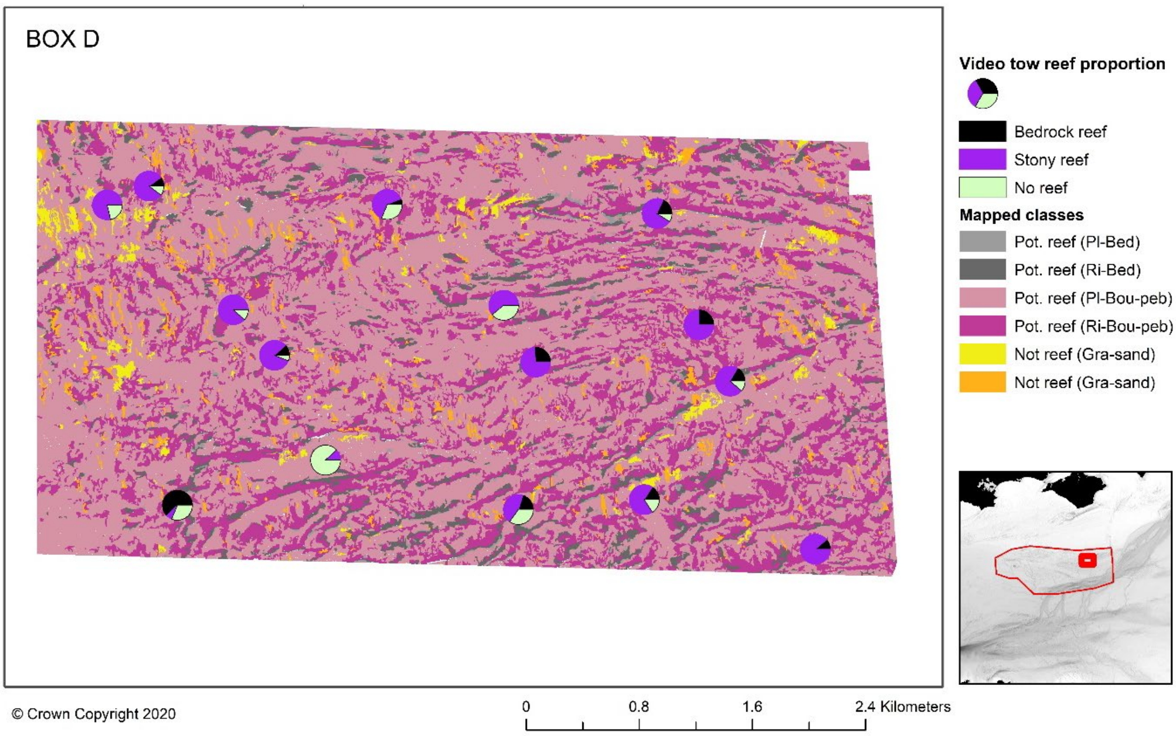

Figure 14. OBIA classification and video tow total Annex I Reef proportions for Box D.

Box E

The central and northern part of the box is characterised by a regular sequence of Jurassic claystone beds, cut in the middle by a broad east-west trending flat channel. The channel and seabed intervals between ridges in the northern part of the bathymetry are occupied by fine sediment. The area shows signs of sediment cover and has been mapped as mainly sand to boulders plane sediment. The two video stations from the area show the presence of Annex I stony reef, relating to a small ridge feature and also a wide gravel to sand area (Figure 15).

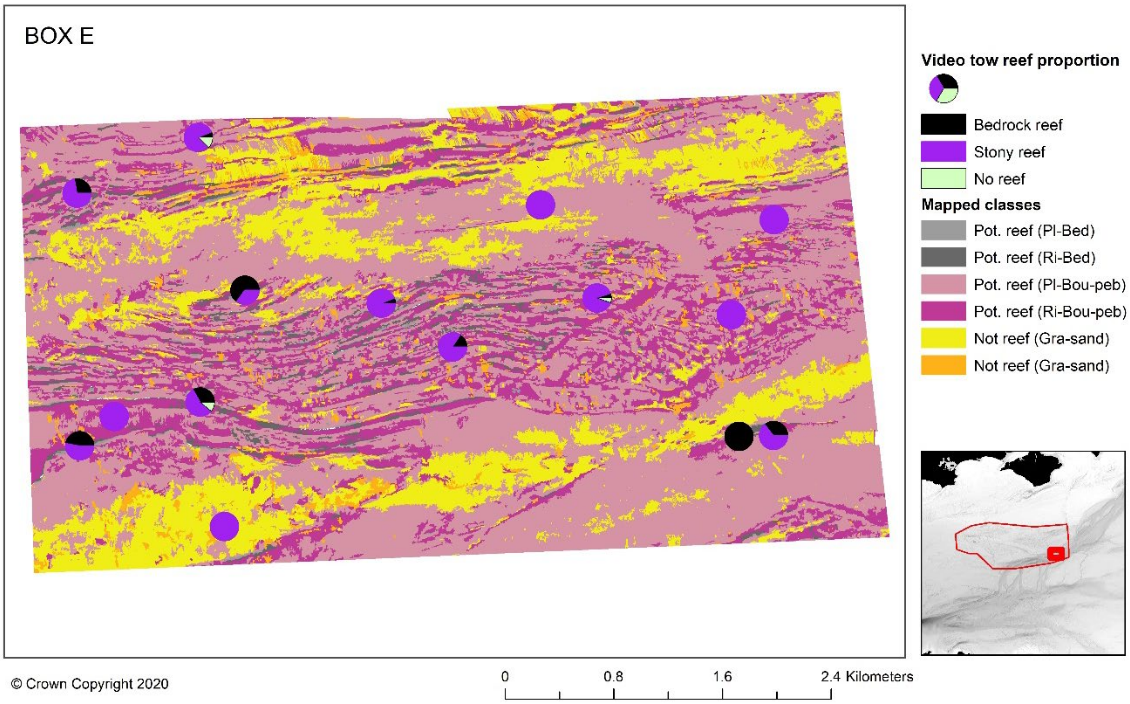

Figure 15. OBIA classification and video tow total Annex I Reef proportions for Box E.

Box F

This box displays the most striking features of the surveyed areas; a thick net of ridges and depressions, with the two most prominent features being a paleo riverine channel cutting perpendicularly through the strata and a low "gap" in between two beds trending north-west to south-east in the central part of the box. These depressions were classified as "Plane – boulders to pebbles" and the few occurrences of "no reef" segments from tow analysis correspond to such features. Bedrock is mostly exposed in the south-west of the box, where also analysis from video tows points toward dominance of bedrock reef. In the rest of the surveyed area the video tow analysis shows a mixture of bedrock and stony reef (Figure 16).

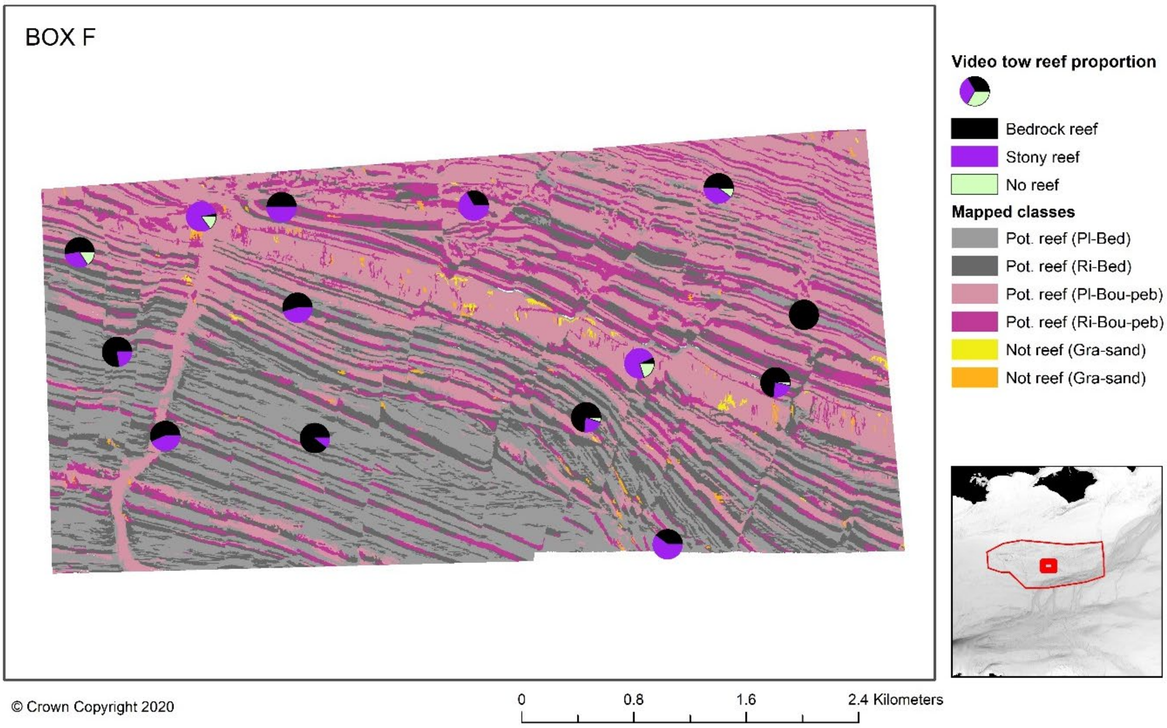

Figure 16. OBIA classification and video tow total Annex I Reef proportions for Box F.

3.2.1 Comparison of mapping predictions between 2017 and pre-existing datasets

In order to test the reproducibility of the mapping of reef extent, a numerical comparison between the OBIA of the pre-existing combined acoustic dataset and the CEND0617 dataset was carried out. The two datasets overlap in limited strips across the study area and a comparison of the results is therefore possible for those strips. The proportional area of overlap of ridge and plane classes between the two maps, that is how well areas categorised as a particular class correspond in both maps, is provided in Table 7.

Table 7. Overlap of classes between the two maps (in %).

	Overlap	Percentage
Single class average	Agree	60.10
	Disagree	39.90
Ridges grouped	Agree	44.87
	Disagree	55.13
Planes grouped	Agree	81.10
	Disagree	18.90

The average proportion of area where both maps agree is about 60%. If grouped by Planes and Ridges, the best agreement is achieved for the plane classes (80%), whilst the ridges are just below 45%. For this group, subclass (e.g. Rock ridge in the pre-existing dataset to rock ridge in the 2017 dataset) averages oscillate between 31 to 44%.

The low comparability between the pre-existing and 2017 datasets may have been exacerbated by the merging and regression applied to the backscatter data in the dataset. This issue is visualised in Figure 17, where higher difference (in Standard Deviation) between the two surveys corresponds strongly with ridge patterns at seabed. Ridges appear more susceptible to discording backscatter values because of the higher roughness and the inclined surfaces that can alter incisively the angle of beam incidence depending on vessel position.

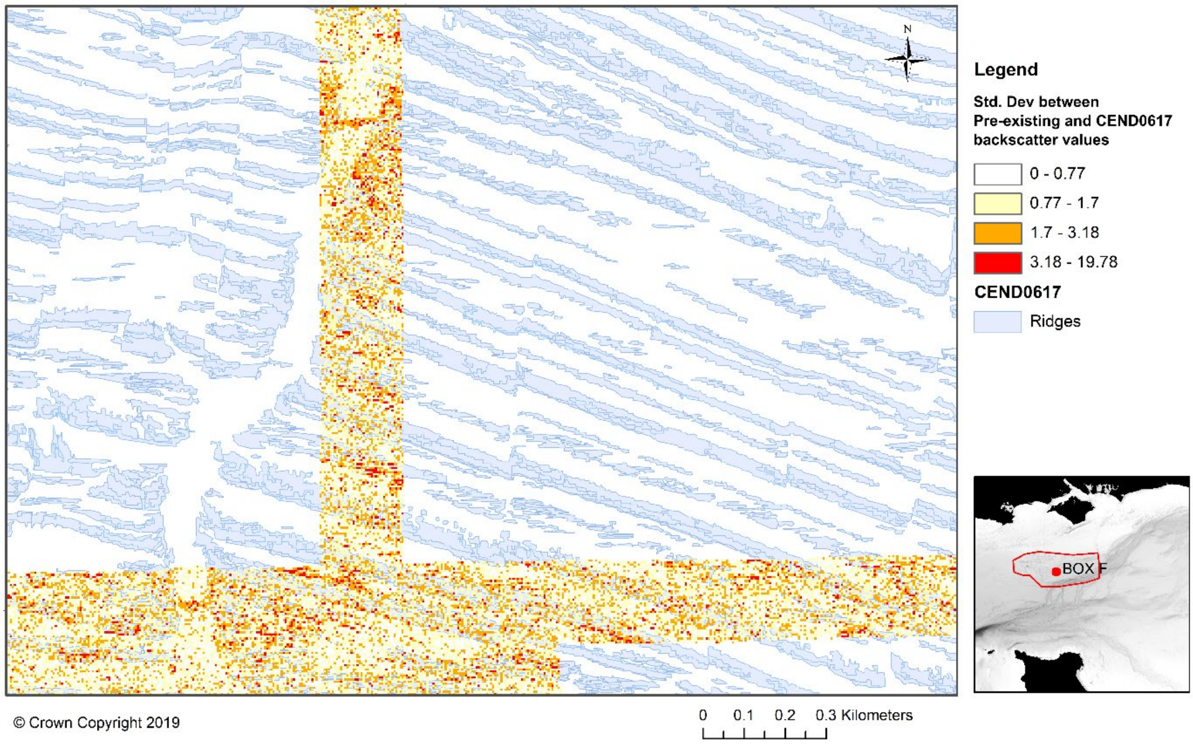

Figure 17. Standard deviation of backscatter reflectance values between the pre-existing and 2017 datasets. Note that the higher difference corresponds to ridge crests.

An equalisation of the datasets was attempted. Decibel values for each corresponding pixel were extracted in the area of overlap between the two survey regions. A regression was then performed on these values using R. Values from the pre-existing dataset were used as the response variable and those from data collected in 2017 as the predictor variable. The results of the regression are shown in Figure 18.

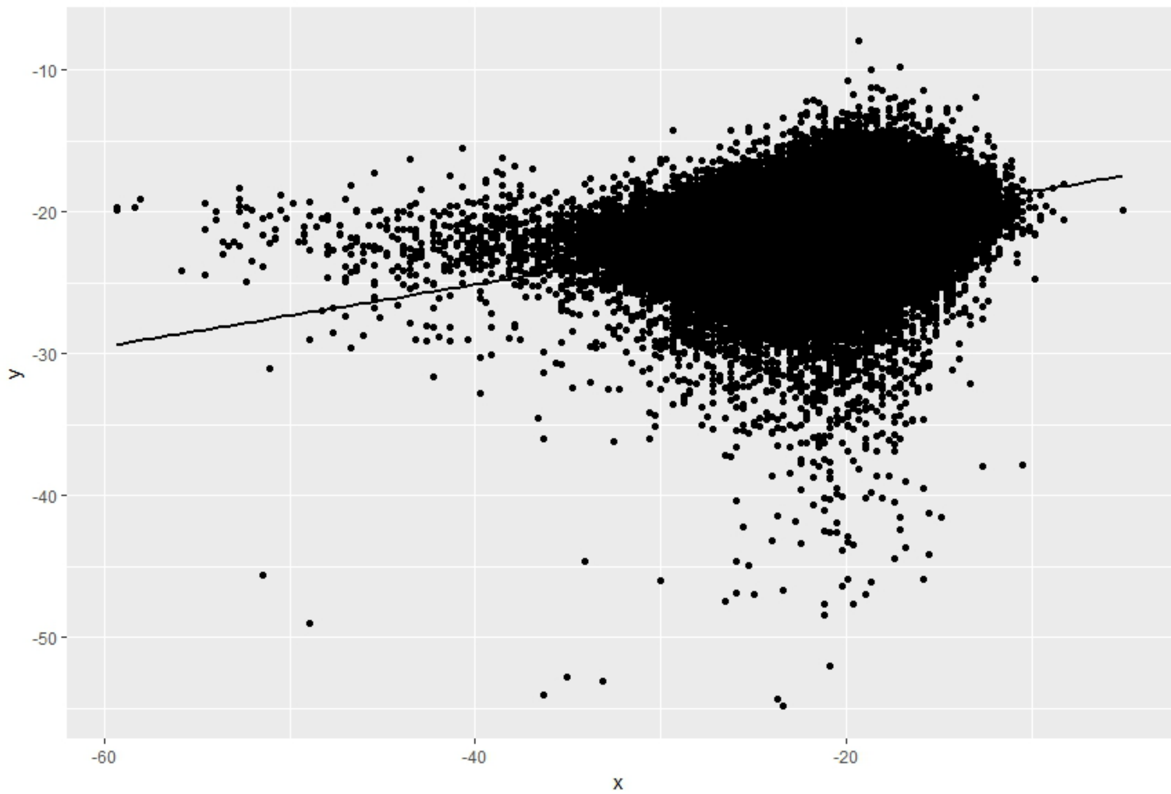

Figure 18. Scatterplot of backscatter reflectance values for the overlapping areas of the pre-existing (Y) and 2017 (X) datasets. The regression line is shown.

The coefficients (Table 8) were then used in the Raster Calculator tool within the ArcGIS 10.5 Geographic Information System (GIS) to equalise the backscatter data intensities between the survey regions as follows: Intercept + (Y × target raster).

Table 8. Results of the regression performed on overlapping backscatter values between the pre-existing and 2017 datasets. Residual standard error: 2.618 on 877319 degrees of freedom; Multiple R-squared: 0.1657; Adjusted R-squared: 0.1657; F-statistic: 1.742e+05 on 1 and 877319 degrees of freedom.

	Estimate	Std. Error	T-value	P-value
Intercept	-4.526403	0.037909	-119.4	$< 2.2*10^{-16}$
Y	0.757432	0.001815	417.4	$< 2.2*10^{-16}$

Mapping of the equalised pre-existing dataset was then carried out and the results compared to the map of the 2017 dataset. No noteworthy improvement of the agreement between the two maps was observed after this procedure, suggesting that the equalisation cannot resolve the differences in the most discordant areas.

3.3 Structure and function – physical structure

3.3.1 Reef topography and characteristics

The topography of Annex I Reef inside the Wight-Barfleur Reef SAC is very variable. The entire survey area is dominated by stony reef, which makes up 71.3% of the analysed video segments. Most of the stony reef encountered is of medium elevation (64 mm – 5 m) and medium reef coverage (40–95%). This is reflected by the extent of the mapped “boulders to pebbles” classes. Bedrock reef is observed in 20.5% of the segments, whilst no reef is present in only 8.2%. Table 9 shows the percentage of each reef type (bedrock, stony and no reef) normalised by their frequency for each mapped OBIA class. The table does not show sharp or definite contrasts that permit the association of one class to a particular reef type, however some useful observations can be made. Bedrock reef is consistently associated to Plane or Ridge bedrock, 40.2% and 32.1% respectively, leaving the remaining 27.7% distributed amongst the other classes. “No reef” is mostly mapped as “Plane – boulders to pebbles” or “Gravel to sand” and “Ridge – gravel to sand” (~84%). Overall, these figures agree with the general association of Annex I Reef to ridges and highly variable seabed.

Table 9. Percentage of Annex I Reef types from video segment analysis for each mapped OBIA classes.

	OBIA classes					
	Plane – bedrock	**Plane – boulders to pebbles**	**Plane – gravel to sand**	**Ridge - bedrock**	**Ridge – boulders to pebbles**	**Ridge – gravel to sand**
None	4.4	16.6	37.8	6.3	5.7	29.2
Bedrock reef	40.2	8.4	2.8	32.1	12.8	3.8
Stony reef	9.0	20.0	19.0	12.0	20.0	19.9

3.3.2 Fine scale morphology and ‘reefiness’ analysis

Figure 19 shows an example of fine scale topographic complexity in station depth profiles from video tow. In this figure, de-trended roughness and peak positions are compared with grain size estimations (bottom right). Roughness and waviness parameters are given in the bottom-centre of the figure. The wide variability in reef topography does not permit a consistent correlation between roughness and waviness variables and reef type. Camera frame tilting in the water column is probably the cause for the very disturbed signal observed in some of the profiles (i.e. B09, B13, C01, C10, C11, C13). However, some consistence in correlation between high roughness and boulder detection with boulders/large cobbles seabed appears to be present.

A separate morphological analysis was run for each separate video segment and the results obtained were used to inform the biological community analysis.

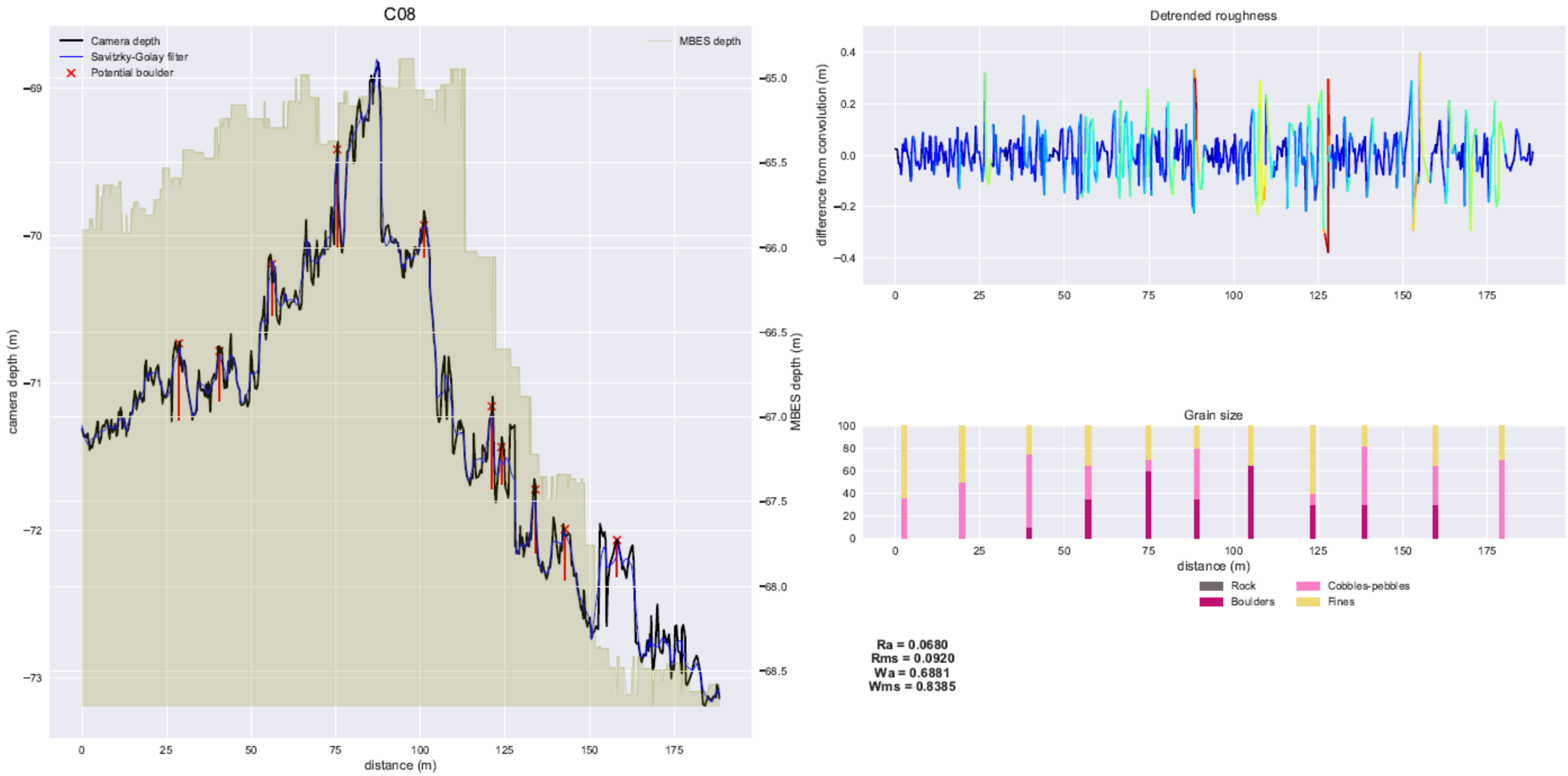

Figure 19. Results of the topological analysis for camera profile C08. MBES bathymetry and camera profile bathymetry are presented on different scales to allow clearer presentation of profiles. Ra = arithmetical mean deviation of the assessed profile from an averaged baseline. Rms = Root mean squared of the profile. Wa and Wms are the arithmetical mean deviation and root mean squared of the profile after the Savitzky-Golay filter (see Section 2.3.4).

3.3.3 Structure and function - epifaunal communities

Following truncation, a total of 88 morphospecies and 35 CATAMI taxa were observed across all 2017 video segments and still images in the Wight-Barfleur SAC (see Appendix 3). All analyses described below used the semi-standardised CATAMI dataset (see Section 2.3.5). On average 15.5 CATAMI taxa (± 2.4 s.d.) were present on 'Bedrock reef', 16.3 (± 3.2 s.d.) on 'Stony reef' and 11.1 (± 3.8 s.d.) on the coarse sediment habitats around the reef. The greatest number of recorded taxa on a transect was 21, whilst the lowest was 7 (Table 10). The most commonly observed taxa, and the taxa with the highest average abundances across the Wight-Barfleur SAC are shown in Table 11.

Table 10. Observed number of CATAMI taxa (S) per transect and density of taxa per m^2 by habitat type.

Habitat	Number of taxa (S)					Density of taxa (S/m^2)			
	N	mean	sd	min	max	mean	sd	min	max
Not reef	9	11.1	3.8	7	16	5.5	1.6	3.5	7.9
Bedrock reef	6	15.5	2.4	12	19	7.6	1.3	5.6	9.4
Stony reef	28	16.3	3.2	9	21	8.2	2.2	4.1	14.3

Using the observed variation in a post-hoc power analysis, 10 and 16 samples would be required for 'Bedrock reef' and 'Stony reef', respectively, to detect a 20% change in number of taxa with 0.8 power (at a significance level of 0.05). For Annex I Reef without sub-categories 18 samples are required.

ANOSIM comparing the habitat types found that whilst both 'Stony reef' and 'Bedrock reef' had epifauna communities significantly different from 'Not reef' ($R = 0.46$, $p = 0.001$; $R = 0.67$, $p = 0.001$, respectively), they were not significantly different from each other ($R = 0.06$, $p = 0.3$).

Seven statistically significant community groups were identified in the cluster analysis of the standardised abundance matrix of CATAMI taxa (Figure 20a). The similarity between samples is also shown in the 2D nMDS ordination in Figure 20b. The 2D ordination stress of 0.23 is high, indicating the plot is not an accurate representation of distances between all samples, although larger patterns are still interpretable. High stress is usually due to insufficient dimensionality in the plot. The 3D ordination stress for the same community matrix is 0.17.

Percent cover of hard substrata was the single environmental variable with the greatest correlation to the community composition (Rho = 0.29, $p = 0.002$). The strongest correlation between community composition and environmental variables was based on two variables, the percent cover of hard substrata and normalised height (Rho = 0.33, $p = 0.001$). The top five variables also included percent cover of cobbles and pebbles, Bathymetry and Profile waviness (Wa component of fine scale topography).

The cluster groups, although statistically significant using the SIMPROF criteria, have variable and overlapping epifaunal communities (Table 13; Figure 20). Within group similarity is below 50% for all SIMPROF cluster groups, except for group C, which consists of the only two transects with bioeroding crust sponges and has a group similarity of 70%. Group B is a single transect and has similar fauna and environmental condition to group F, separated most likely by the high abundance of 'Foliaceous soft bryozoa', which are not present in the transects comprising group F.

Table 11. Characterisation of the most commonly occurring and abundant taxa at Wight-Barfleur Reef SAC. The cumulative list of 25 taxa includes those that occur in at least 30% of the samples or have a median SACFOR when present of at least 3.

Taxon	Occurrence in transects (%)	Number of morphotaxa included
Tubeworms	100%	5
Unstalked solitary ascidians	100%	4
Thin encrusting sponge	98%	4
Faunal turf	95%	3
Thick encrusting sponge	95%	8
Gastropods	86%	5
Other anemones	81%	6
Hydrozoa erect	81%	4
Massive simple sponges	81%	7
Massive ball sponges	77%	7
Dendroid soft bryozoa	70%	2
Unstalked colonial ascidians	58%	7
Hydrozoa bushy	49%	1
Massive soft corals	49%	1
Erect palmate sponges	44%	1
Sea stars	40%	3
Bivalves	40%	2
Colonial anemones	33%	1
Spider crabs	28%	2
Solitary attached stony corals	23%	1
Brittlestars	7%	2
Nutcrabs	7%	1
Feather stars	5%	1
Bioeroding crust sponges	5%	1

The two groups most different from each other, group A and group G (between-group dissimilarity 89.7%), are the opposite ends of a continuum of increasing hard substrata coverage and fine scale topographical complexity, mirrored by increasing taxonomic diversity and abundance. Transects in group A are classified as 'Stony reef' and 'Not reef', have low hard substrata cover, low fine scale topographic variability and are located at the bottom end of local slopes. The most common taxa are tubeworms, Faunal turf, Thin encrusting sponges and unstalked solitary ascidians. However, abundances of all taxa are low. All transects in group G are classified as 'Stony reef'. In contrast to group A, transects in group G have a high coverage of hard substrata and fine scale topographic variability, mainly consisting of boulders and cobbles, and are located on the sides of local slopes.

Group G has the highest taxonomic diversity and abundance, with colonial anemones, other anemones, solitary attached stony corals, branching hard bryozoans, Hydrozoans, cup sponges, massive ball sponges, massive simple sponges and encrusting sponges all frequent and abundant. Groups D, E and F are intermediate between the two ends of the spectrum (Table 13). Groups D and F contain most of the transects classified as 'Bedrock reef'.

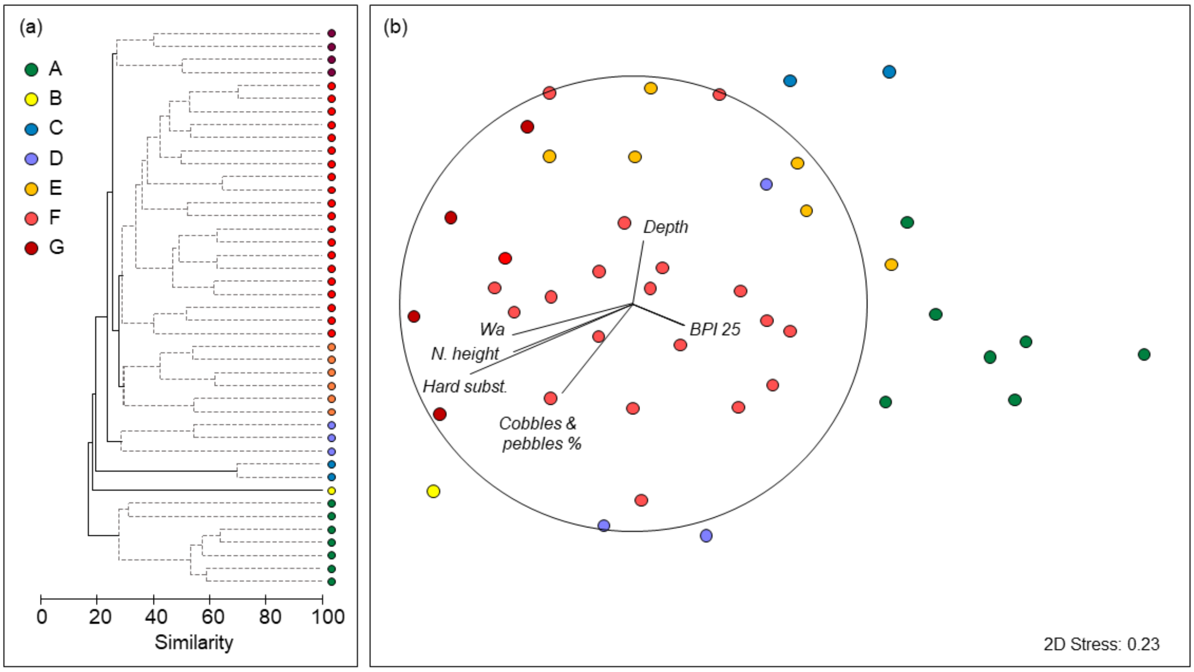

Figure 20. Results of the cluster analysis with SIMPROF (a) and nMDS plot with the cluster groups (b). The six most influential environmental drivers of community structure (as determined by the BEST analysis, Rho = 0.3, p = 0.001) are shown as vectors on the nMDS plot. Wa = Waviness component of fine scale topography. N. height = Normalised height. BPI = Bathymetric Position Index with a radius of 25 m.

Indicator species analysis did not find especially strong candidates for indicators. The only significant indicator values were for groups B (Foliaceous soft bryozoa) and C (Bioeroding crust sponges), which consist of one and two transects respectively. Solitary attached cup corals are prominent and frequent in group G, and would be a significant indicator, were it not for their presence in the one transect that comprises group B (Table 12). The lack of significant indicator species reflects the overlap of species presence and abundance among the different groups. Indicator species analysis is based on a measure of exclusiveness for a species in a group, whereas the cluster groups at Wight-Barfleur Reef are largely examples of the same rocky reef habitat with local variations in epifauna assemblage composition and abundance. Consequently, no specific indicator species are likely to be applicable for monitoring.

Table 12. Indicator values for selected taxa ($p \leq 0.05$). N = Number of transect in the group.

Group (N)	Taxon	Indicator value	p-value
B (1)	Massive soft corals	0.45	0.050
	Foliaceous soft bryozoa	1.00	0.028
C (2)	Bioeroding crust sponges	1.00	0.003
G (4)	Solitary attached stony corals	0.68	0.051

Figure 21 shows the spatial distribution of the cluster groups across the reef feature.

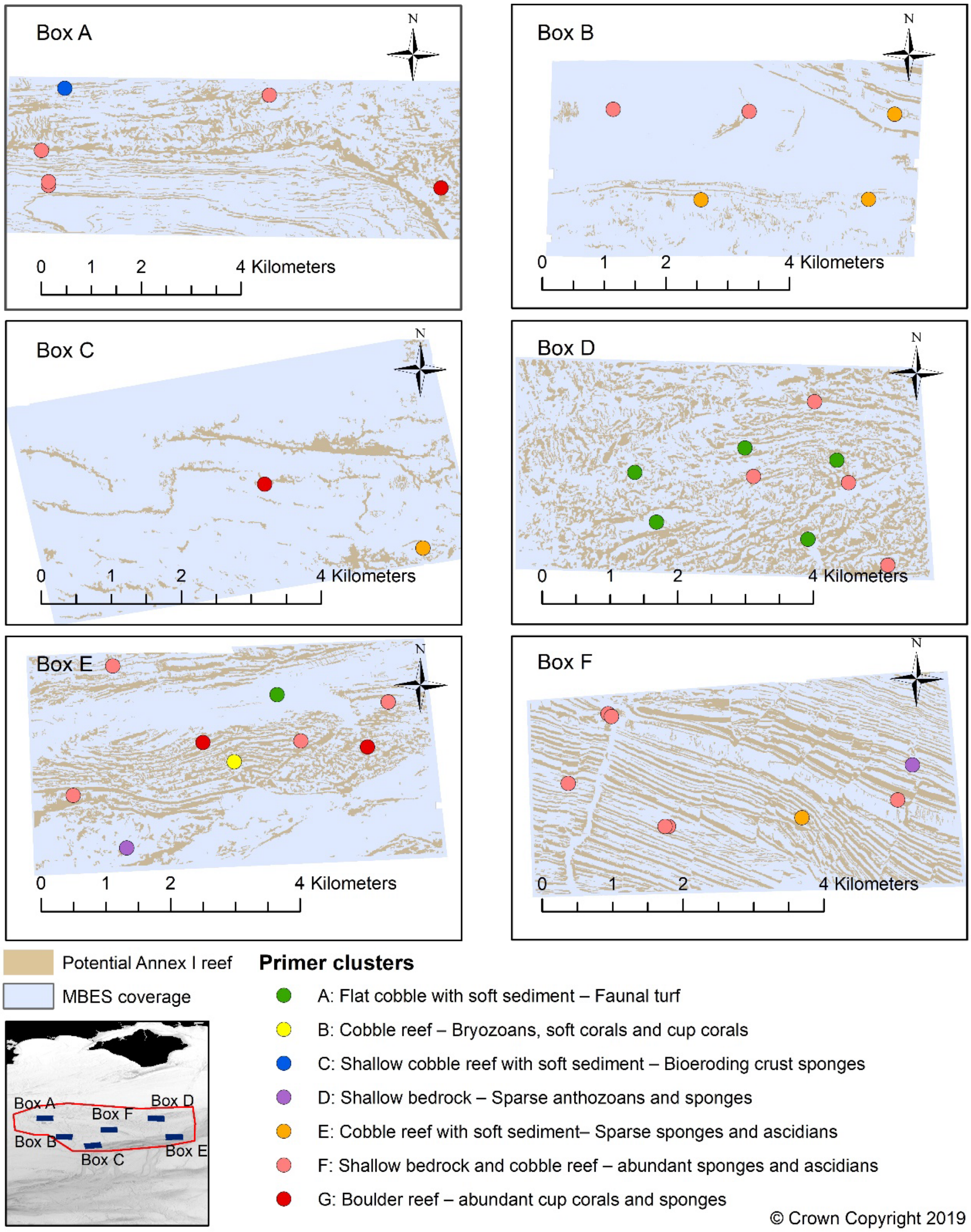

Figure 21. Spatial distribution of community groups derived from hierarchical clustering with SIMPROF.

Table 13. Constituent transects, within group similarity, CATAMI taxa with largest SIMPER contributions, mean and standard deviation (s.d.) of number of taxa and the ranges of environmental variables (identified in BEST) for constituent transects for SIMPROF cluster groups.

Cluster group	Stations (no. segments per station)	Similarity	Taxa in common within groups (explaining 70 % of the within group similarity)	Mean S (and s.d.)	Group environmental thresholds – mean (standard deviation)
A Flat cobble with soft sediment – Faunal turf	D01 (1) D08 (1) D12 (1) D13 (1) D15 (1) E12 (2)	41.4	Tubeworms Faunal turf	9.3 (2.3)	Cobbles & pebbles: 30.6% (12.1) Bathymetry: -60.3m (7.8) Normalised height: 0.4 (0.09) Profile waviness: 0.022 Wa (0.006) Hard substrata: 31.3% (12.5)
B Cobble reef – Bryozoans, soft corals and cup corals	E03 (1)	N/A	N/A	N/A	N/A
C Shallow cobble reef with soft sediment – Bioeroding crust sponges	A10 (1) B04 (1)	70.0	Bioeroding crust sponges	16 (1.4)	Cobbles & pebbles: 27.5 %(3.5) Bathymetry: -55.8 m (9.3) Normalised height: 0.5 (0.36) Profile waviness: 0.016 Wa (0.023) Hard substrata: 27.5 % (3.5)
D Shallow bedrock – Sparse anthozoans and sponges	E08 (1) F06 (2)	37.5	Other anemones Massive soft corals Unstalked solitary ascidians	13 (2.6)	Cobbles & pebbles: 28.8 % (5.9) Bathymetry: -58.9m (14.8) Normalised height: 0.5 (0.16) Profile waviness: 0.042 Wa (0.014) Hard substrata: 55.3% (17.8)
E Cobble reef with soft sediment– Sparse sponges and ascidians	B02 (1) B04 (1) B08 (1) C12 (1) E10 (1) F04 (1)	38.7	Tube-like sponges Massive cryptic sponges Tubeworms Dendroid soft bryozoa Other anemones Unstalked solitary ascidians Hydrozoa bushy Hydrozoa erect	16.2 (2.6)	Cobbles & pebbles: 25.7 % (10.3) Bathymetry: -63.4 m (7.1) Normalised height: 0.5 (0.15) Profile waviness: 0.036 Wa (0.015) Hard substrata: 37.3 % (16.6)

Cluster group	Stations (no. segments per station)	Similarity	Taxa in common within groups (explaining 70 % of the within group similarity)	Mean S (and s.d.)	Group environmental thresholds – mean (standard deviation)
F Shallow bedrock and cobble reef – abundant sponges and ascidians	A04 (2) A05 (1) A07 (1) B03 (1) B09 (1) D03 (1) D04 (1) D06 (1) D07 (1) E04 (1) E07 (1) E10 (1) E15 (1) F02 (1) F03 (2) F07 (2) F10 (1)	36.4	Thick encrusting sponge Massive ball sponges Massive simple sponges Faunal turf Thin encrusting sponge Massive soft corals Tubeworms Erect palmate sponges Unstalked solitary ascidians Hydrozoa erect	16.1 (2.7)	Cobbles & pebbles: 42.5 % (22.3) Bathymetry: -54.7 m (5) Normalised height: 0.6 (0.09) Profile waviness: 0.035 Wa (0.022) Hard substrata: 60.6 % (15.1)
G Boulder reef – abundant cup corals and sponges	A08 (1) C08 (1) E11 (1) E13 (1)	33.3	Solitary attached stony corals Cup sponges Massive simple sponges Hydrozoa bushy Massive soft corals Hydrozoa erect Thick encrusting sponge Thin encrusting sponge	18.8 (3.2)	Cobbles & pebbles: 40.1 % (20.3) Bathymetry -67m (8.9) Normalised height: 0.6 (0.12) Profile waviness 0.098 Wa (0.053) Hard substrata 72.9 % (24.2)

3.4 Structure and function - total epifauna coverage

Total coverage of epifauna was highly variable across all video sub-segments in all habitat types (Table 14). The mean coverage was highest on bedrock reef, but values range from 1 to ~ 100 % coverage for both reef types. Coverage values over 100% result from the summing of estimated coverage for all taxa, which sometimes overlap. Correcting the total faunal coverage to account for the percent coverage of suitable substrata allows a more standardised comparison by removing the variability arising from the area of available substrata. The range of epifauna coverage values remains wide and highly variable even when related to the available attachment surface by dividing total faunal coverage by the total hard substrata coverage in a segment (relative % coverage, Table 14).

Table 14. Total epifauna coverage, coverage of hard substrate and the relative coverage hard substrate by fauna (fauna/hard substrate) in each habitat category. Values given are mean (minimum – maximum).

Habitat type	Number of segments	Total % coverage	Hard substrate % coverage	Relative % coverage
Reefs (Bedrock)	64	55 (1–101)	64 (7–95)	85 (1–220)
Reefs (Stony)	125	32 (1–115)	48 (5–95)	67 (4–410)
None	42	6 (0–58)	13 (0–75)	36 (0–150)

The high variability is reflected in the results of a post-hoc power analysis which indicates that 169 and 331 samples would be required for ‘Bedrock reef’ and ‘Stony reef’, respectively, to detect a 20% change with 0.8 power (at a significance of 0.05). The high number of samples required reduces the applicability of epifauna coverage to monitoring. To make the metric viable, further narrowing down of environmental conditions to select comparable sub-sets of bedrock and stony reef is needed.

Although epifauna coverage is most strongly affected by the available hard substrate, it is also strongly influenced by depth, position on a slope (enumerated by normalised height and BPI, see Appendix 6) and the proportion of hard substrata made up of bedrock as opposed to other hard substrata (Table 15). Other variables with some influence on epifauna coverage include local and wider topographic roughness (Ra/Rms, Wa/Wms and TRI), and the proportion of cobbles and pebbles. Together, percentage of hard substrate, bathymetry, normalised height, percent bedrock, BPI 25 and local topographic roughness explain 63.4% of the variability in epifauna coverage (Table 16). Higher coverage occurs in shallower water with high percentage of hard substrate available as an attachment surface. Places that are elevated from the surrounding seabed have higher coverage, but position on the reef structure is important. The normalised height indicates position on a local elevation, with values ranging from 0 (at the bottom of the slope) to 1 (at the top of the slope). Highest coverage occurs at normalised heights of around 0.6, indicating the sides of a reef, as opposed to the top or bottom. Higher proportion of bedrock and lower local topographic roughness also indicate higher epifauna cover (Figure 22).

Table 15. Environmental variables associated with 5 m video sub-segments. Tick-marks indicate which variables were included in a GAM model explaining the environmental drivers of total epifauna coverage. Deviance explained by each variable in a single variable model is given to indicate variable importance.

Variable	Summary	Included	Dev. Exp. (%)
Bedrock %	Percent cover of bedrock in segment.	√	24
Boulders %	Percent cover of boulders 64 mm to > 1,024 mm in segment.		0
Cobbles and pebbles %	Percent cover of cobbles and pebbles in segment.		2
Soft sediment %	Percent cover of gravel, and mud in segment.		49
Hard substrata %	Percent cover of bedrock, boulders, cobbles and pebbles in segment.	√	49
Bathymetry	Mean depth of associated image object.	√	42
Slope height	Mean slope height of associated image object (see Appendix 6).		0
Normalised height	Mean normalised slope height of associated image objects (see Appendix 6).	√	40
TRI	Mean topographic roughness index of associated image objects (see Appendix 6).		2
BPI 25	Mean BPI 25 of associated image objects (see Appendix 6).	√	6
BPI 10	Mean BPI 10 of associated image objects (see Appendix 6).		4
BPI 5	Mean BPI 5 of associated image objects (see Appendix 6).		3
Profile roughness (Ra/Rms)	Profile roughness associated with video segment (see Section 2.4.5).	√	1 / 2
Profile waviness (Wa/Wms)	Profile waviness associated with video segment (see Section 2.4.5).		2 / 3

Table 16. GAM model summary for the total epifauna coverage. Edf = estimated degrees of freedom, Ref. df = reference degrees of freedom, UBRE = Unbiased Risk Estimator score.

	Estimate	**Std. Error**	**t-value**	**p-value**
(Intercept)	3.08	0.02	166.1	< 0.0001
	Edf	**Ref. df**	**F-value**	**p-value**
Hard substrate %	2.98	3	461.2	< 0.0001
Bathymetry	2.43	3	262.9	< 0.0001
Normalised slope height	2.98	3	210.7	< 0.0001
Bedrock %	2.74	3	49.9	< 0.0001
BPI 25	2.20	3	54.3	< 0.0001
Profile roughness (Rms)	2.80	3	63.5	< 0.0001
N	233			
Adjusted R^2	0.57			
UBRE	10.8			
Deviance explained	63.4%			

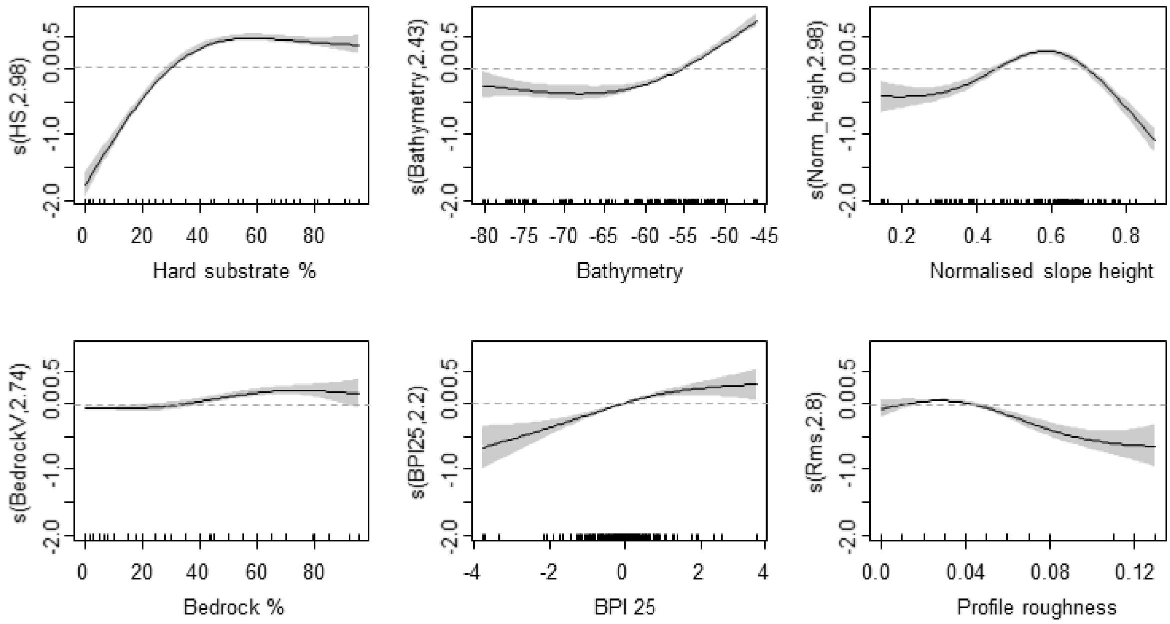

Figure 22. Partial environmental variable response plots for the GAM model of total epifauna coverage.

3.5 Supporting processes

Results from the tidal model show strong peak flood and ebb magnitudes (1.6–2.5 ms[1]) for the entire SAC. Tidal current directions are predominantly on an east–west axis (Figure 23).

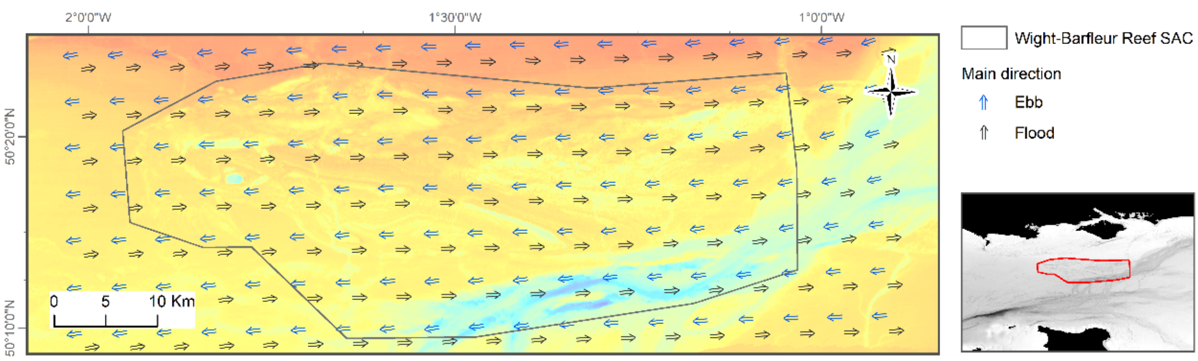

Figure 23. Results of the tidal model for Wight-Barfleur Reef SAC.

Temperature, salinity and turbidity measurements for each of the tow stations were collected. An average temperature of 11.05 ± 0.14 (1σ), salinity of 35.18 ± 0.23 (1σ) and turbidity (Formazin Turbidity Unit) of 12.48 ± 0.90 (1σ) was recorded for all the stations. No significant variability within station or differences between stations according to water depth or location were observed. For this reason, a study of these measurements was not carried forward.

Wight-Barfleur Reef SAC seabed is situated in a moderate to high energy environment. Bed shear stresses, of over 10 N/m^2 (Aldridge *et al*. 2015) interact with the seabed causing fine sediment migration and coarse sediment reworking. It is likely that small-scale variations in hydrodynamic energy, linked to topographical constraints cause local shading effects and acceleration of currents. Net direction of bedform migration observed on the bathymetry data appears to be related to main direction of tidal currents at peak flood (Figure 24). A slight asymmetry in sandwaves profiles, showing a steeper west-facing stoss side, indicate an overall westwards migration.

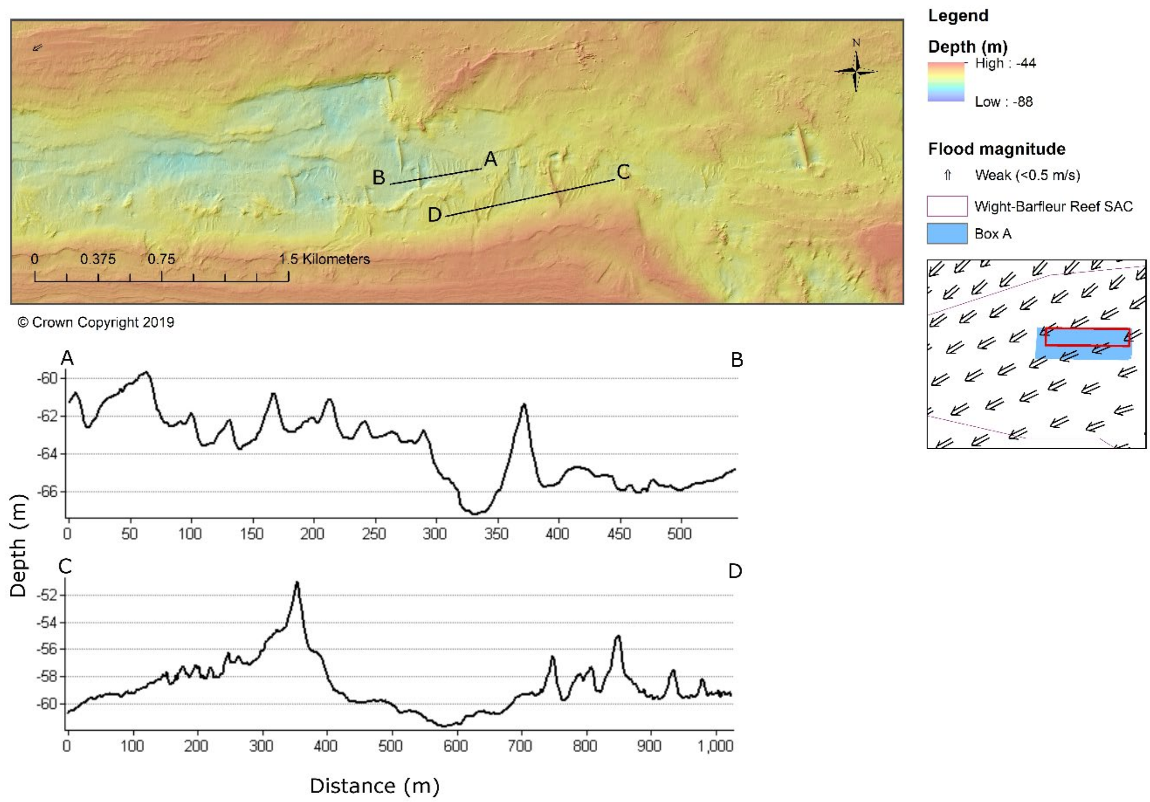

Figure 24. Correlation of mobile sediment bedforms and peak flood direction in Wight-Barfleur Reef SAC.

3.6 OSPAR Threatened and/or Declining Species and Habitats and non-indigenous species (NIS)

No OSPAR Threatened and/or Declining Species and Habitats or NIS were observed from images or video segments. A list of NIS is provided in Appendix 5 for reference (Table 21 and Table 22).

3.7 Marine litter

A total of 27 occurrences of litter were observed spread across 19 stations (Table 17; Figure 25). The standardised categories and sub-categories for sea floor litter, as defined by the Convention for the Protection of the Marine Environment of the North-East Atlantic (OSPAR), the International Council for the Exploration of the Sea (ICES), and the International Bottom Trawl Survey (IBTS) for the North-East Atlantic and Baltic, are listed in Appendix 4.

Table 17. Litter observed in drop camera transects at Wight-Barfleur SAC.

Litter category	Occurrences
A4. White plastic lid	1
A5. Fishing line (monofilament)	2
B7. Metal cable	1
B8. Metal Pipe	1
D2. Bottle	16
E1. Clothing/ Rags	2
F2. Rope	1
F5. Other	1
F5. Red cloth	1
F5. Small pipe	1

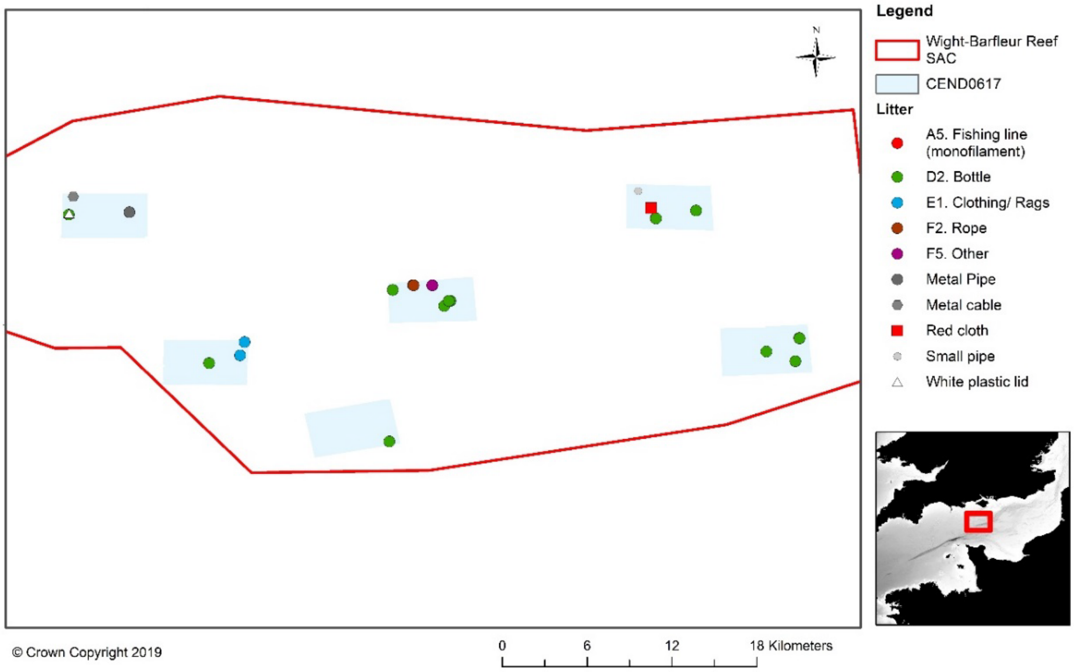

Figure 25. Location of observed litter items by MSFD category.

3.8 Anthropogenic activities and pressures

One wreck was visible in the MBES bathymetry in box B.

4 Discussion

This discussion presents evidence for future assessment and monitoring of designated features of the Wight-Barfleur Reef SAC, as required to achieve the report objectives stated in Section 1.3.2.

Section 4.1 is dedicated to the limitations in mapping Annex I Reef extent and distribution. It presents the final updated EUNIS habitat map and discusses the improvements and changes related to the previous maps. Section 4.2 discusses the coverage and composition of epifaunal communities present on the reef in the context of future monitoring needs.

4.1 Physical aspects of the Annex I Reef

4.1.1 Mapping the extent and distribution

Due to the seabed complexity at Wight-Barfleur Reef SAC, the very coarse resolution Annex I Reef features map derived from the Defra Astrium DEM is not quantitatively relatable to the MBES data, and a comparison can be made only from a qualitative point of view. The comparison between Annex I Reef and ridge classes from CEND0617 MBES data is shown in Figure 26.

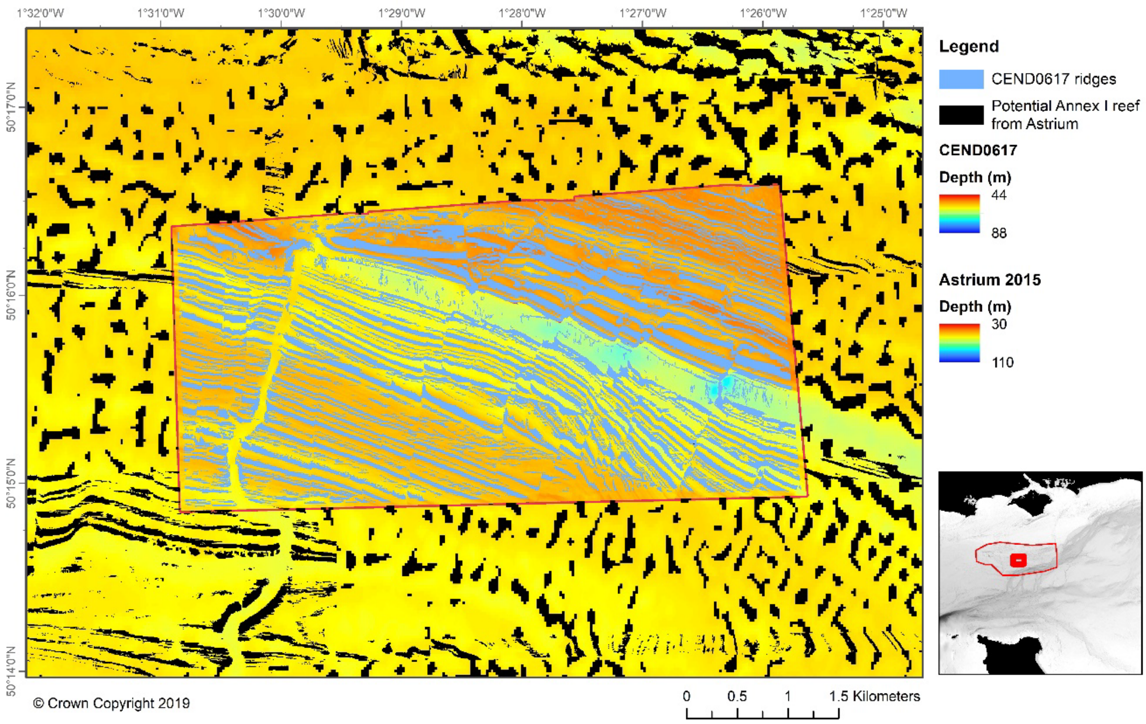

Figure 26. Comparison between Defra (Astrium) Annex I reefs and “ridge” class mapped on the CEND0617 acoustic data.

The detail provided by the new mapping is much higher than that derived from the Defra DEM. The effect of interpolation from multiple sources with varying resolution is evident in the example shown in Figure 27. Where the DEFRA DEM is based on coarser resolution soundings from single-beam echosounder mapping the ridges seen in the MBE data appear as separate knolls. Nevertheless, a general correspondence between the distribution of the earlier mapped macrostructures and MBES ridge classes is evident, and the coarser map can be used to identify and target areas of high macro-topographic unevenness, which indicate areas likely to contain reef.

Comparison of mapping predictions between 2017 and pre-existing datasets

The numerical comparison between the OBIA of the pre-existing acoustic dataset and the CEND0617 dataset presented in Section 3.2.1 yielded low results, with average percentage of agreement overlap of about 60%. This low overlap cannot be attributed to changes of the morphology in the intervening five years, which are not sufficient to move or erode the coarse-grained or bedrock seabed features. It can instead be attributed to two main factors:

1. morphological imprecisions - linked to MBES resolution and object creation by eCognition,
2. sediment type imprecisions – linked to incongruent values from the backscatter data.

The general low areal correspondence between ridges can be attributed to the first factor. The pre-existing dataset has a maximum resolution of 5 m, against the 2 m resolution in the 2017 data. This implicates grainier and less detailed seabed features in the pre-existing data, consequently many smaller crests, mounds and other minor features are levelled out in the pre-existing dataset map. Furthermore, this difference influences greatly the delineation of objects in the semi-automated mapping process, leading to fewer and larger objects in the pre-existing dataset map, and ridges can either be lost in a predominantly plane area or clumped up as a "macro-ridge". However, when the two datasets are compared visually, an excellent concordance in number, extent and position of the mapped ridge features is clearly observable. For example, in Figure 27 the width, strike and pattern of the ridges is practically equivalent in both maps.

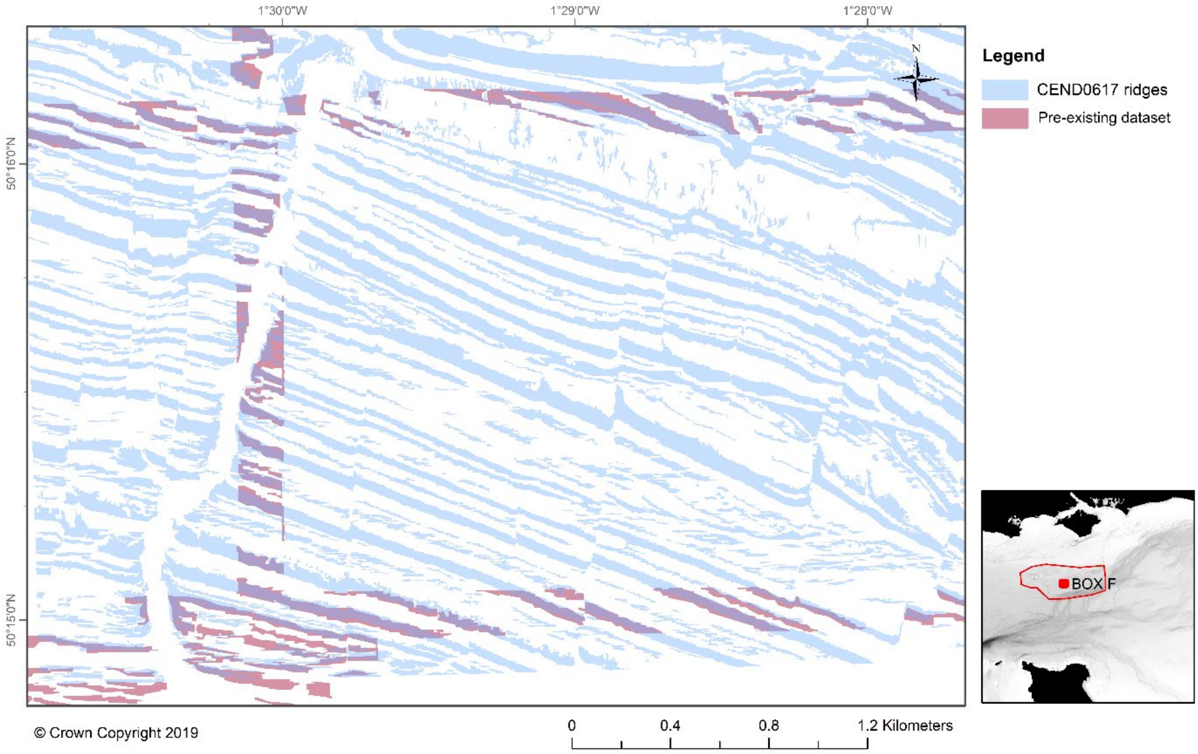

Figure 27. Correlation between ridges mapped on the pre-existing and CEND0617 (2017) datasets. A good correlation in terms of pattern and extent can be observed.

The low overlap figures presented in the table are therefore an underestimation of the correspondence between the two maps, inflated by the fine differences in the detected perimeter of the ridges, caused by the technical limitations explained above. Mapping of same resolution bathymetry data would probably resolve this issue.

The second issue is instead linked to the imprecision in the correlation across ridge sediment type, especially boulders to pebbles and rock ridges. This problem is related to the poor comparability in the backscatter data from the two datasets, on which the sedimentological distinction is based (see also the data regression in Section 3.2.1). Backscatter intensities are influenced by various factors, amongst which are substrate hardness, roughness at seabed, distance and angle of incidence. Different survey setups and transect line positioning affect the backscatter response (e.g. the angle of incidence will change, dictated by relative position of the vessel to the feature).

To monitor the reef features and accurately compare the results with previous years a consistent survey method should be adopted, using the same resolution and consistent collection of acoustic data.

Reef extent and distribution

A definitive map or reef extent cannot be created for the entire SAC. Annex I Reef has been observed in all the groundtruthing stations and presents a wide variety of morphologies and substrate type. However, the updated habitat map can be used to distinguish areas that are more prone to contain Annex I Reef from less prone areas.

The classes “Ridge – bedrock”, “Plane – bedrock” and “Ridge – boulders to pebbles” should be considered as “reef prone”. “Plane – boulders to pebbles” is a mixed class that cannot lead to any definite conclusion, however most of the groundtruthing stations related to this class contained stony reef. “Plane – gravel to sand” should be considered as unlikely to contain any Annex I Reef, whilst “Ridge – gravel to sand” almost certainly does not contain any reef.

The new evidence on the distribution of habitats derived from OBIA and interpretation of video tow data was used to update the existing EUNIS habitat map of the Wight-Barfleur Reef SAC and surroundings (Figure 28), modified after Barrio-Froján *et al*. (2019).

Wight-Barfleur Reef SAC displays a highly complex seabed habitat, composed of a mosaic of bedrock reef, stony reef, coarse sediment and, in places, veneers of sand and constructional sediment bedforms. The EUNIS classification proposed for Wight-Barfleur Reef in Barrio-Froján *et al*. (2019), namely ‘X33 – Mosaics of mobile and non-mobile substrata in the circalittoral zone’, is still considered the most appropriate outside of the intensively surveyed boxes. Information on the distribution of reef gained by OBIA analysis (the coarse sediment and bedrock ridges), complemented by previous analysis is displayed as ‘A4 Circalittoral rock and other hard substrata’.

Areas mapped as “Plane – coarse sediment” were classified as mosaics of mobile and non-mobile substrata in the circalittoral zone and they contain patches of Annex I Reef; fine sediment was translated to ‘A5.14 Circalittoral coarse sediment’. As for the previous report, more detailed assessment at EUNIS Level 4 was not possible, as no information on sediment composition was available; however, it is unlikely that muddy sand is present in the survey area due to the high energy regime. The sandy habitats (fine sediment ridges) observed could be most likely classed as ‘A5.25 Circalittoral fine sand’ and ‘A5.27 Deep circalittoral sand’ (in the palaeovalley).

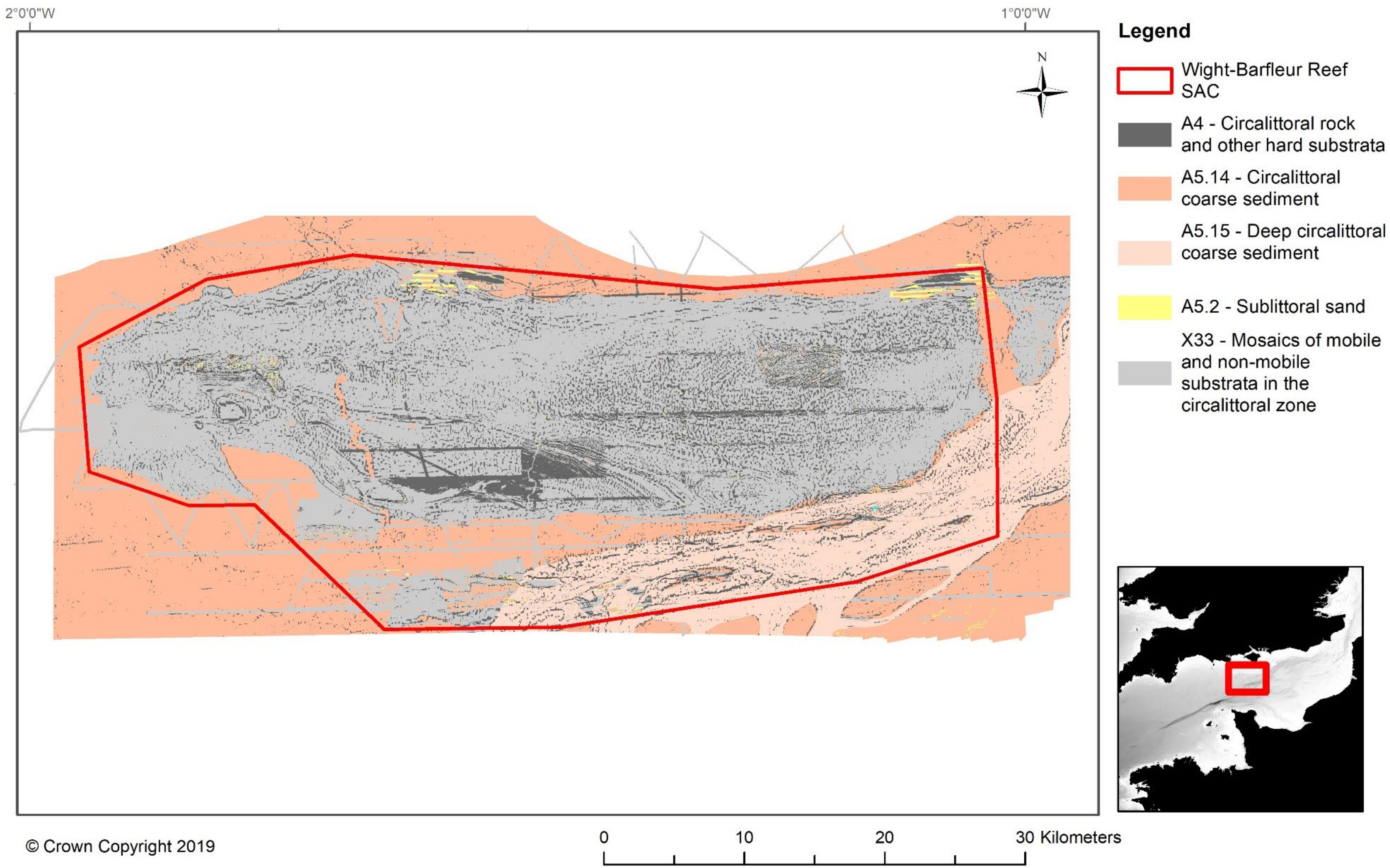

Figure 28. Updated EUNIS map for Wight-Barfleur Reef SAC and surroundings. Circalittoral coarse sediment in the SAC could include Annex I Reef.

4.1.2 Reef structure

Mapping reef features at Wight-Barfleur SAC presented multiple levels of topographical/morphological complexity, and the most appropriate methods of representing this complexity should inform future monitoring plans. A “nested approach” is proposed in the description of Annex I Reef at Wight-Barfleur and it is described below.

Morphological analysis: a nested approach

One of the prescribed outputs requested for Wight-Barfleur Reef SAC was the comparison between different levels of data collected (i.e. large-scale Astrium, acoustic data (MBES), HD imagery and camera frame altimetry) in order to monitor the extent and distribution of Annex I Reef. Whilst such a comparison is feasible on a broad qualitative level, as presented in the results section, and some mapped classes are indeed more likely to contain Annex I Reef, no strong quantitative or statistical correlation can be made between data types due to the considerable differences in sampling resolution. To better visualise this concept, Figure 29 has been prepared.

From a morphological point of view, Annex I Reefs (bedrock and stony) are defined as rocky areas that rise from the surrounding seafloor or are made up of either stone (i.e. loose coarse sediment like pebbles, cobbles and boulders). It is important to notice that, on the basis of this definition, the vertical expression of Annex I Reef varies between centimetre and metre scale. In Figure 29, the top boxes show the 2017 MBES data at a resolution of two square metres in two sites in box D. At this resolution substantial information about the major structures at the seabed (e.g. channelling, bedrock structure, mobile sediment forms) can be derived. However, when zooming in further, to the level which corresponds to the length of the video and camera tow, a superior degree of resolution is apparent, where the acoustic data is unable to resolve the detail shown in the camera altitude profile. Here, the roughness of the seabed is displayed at a resolution between 0.2 to 0.8 m. Although very detailed, these profiles show features still one order of magnitude lower in size compared to the imagery dataset (Figure 29), where single small pebbles can be observed. The “reefiness” of a location based on the analysis of the photos and videos, which encompasses features as subtle as cobble pavements (centimetre to decimetre scale), cannot therefore be compared to the “reefiness” extrapolated by the analysis of acoustic data, which cannot account for features smaller than ~2 m wide. These limitations lead to the conclusion that mesoscale (metres to tens of metres) features mapped on acoustic data do not necessarily imply the presence of Annex I Reef sub-types, and that the habitat map should be read with caution.

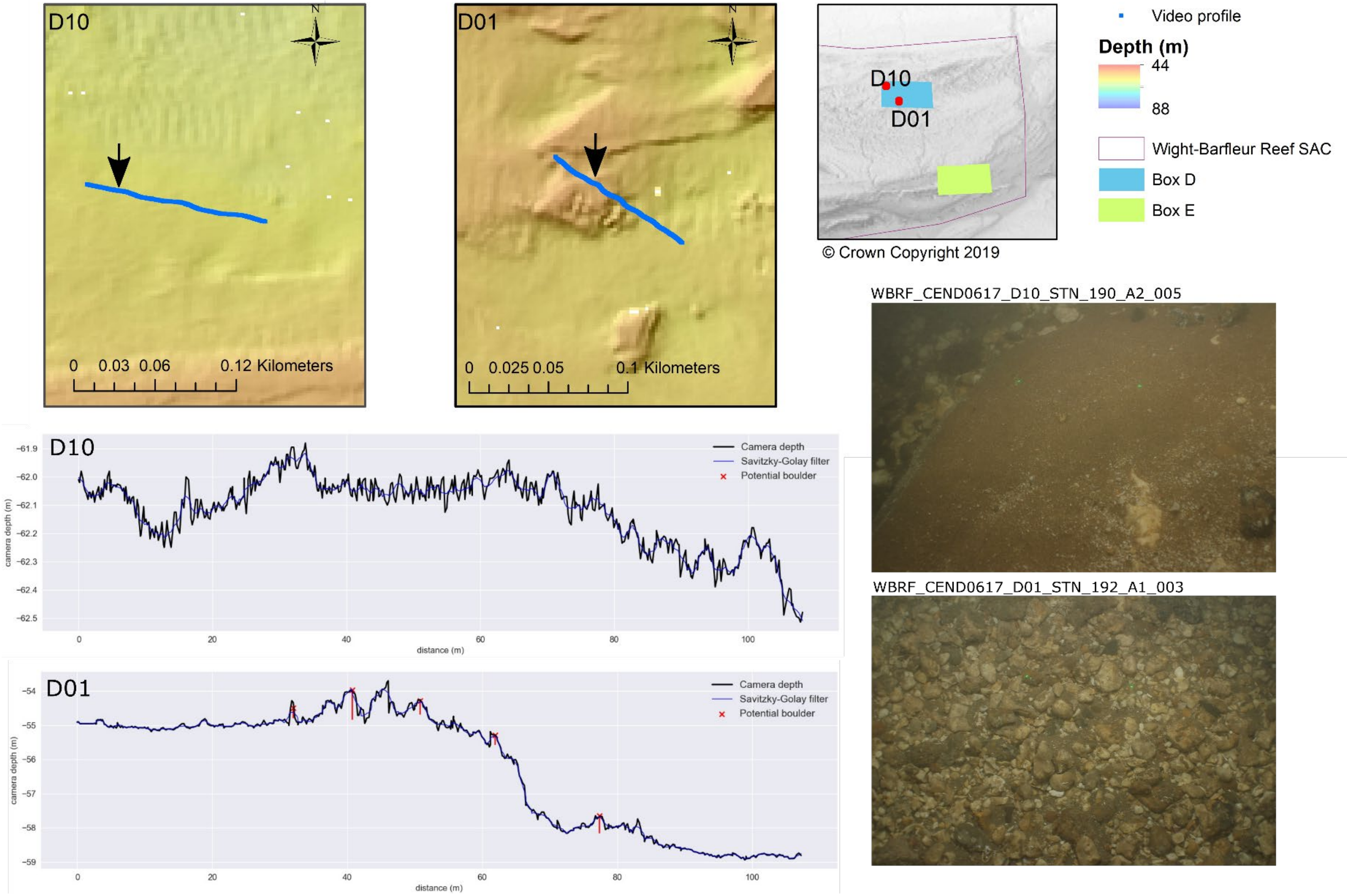

Figure 29. Comparison between three different data “layers”: MBES bathymetry on top, camera altitude profiles (bottom left) and camera stills (bottom right). Each dataset offers a different degree of resolution (from low to high).

It is therefore important that only similar sized features are compared in future monitoring. The larger scale datasets (e.g. Defra DEM) can be used to predict presence or non-presence of large seabed features (i.e. large-scale structural unevenness at seabed) at certain locations. Subsequently the higher resolution offered by MBES surveys will be better suited to delineate the finer topography in higher detail, isolating areas of high rugosity from flat surfaces where reef development is less likely. The finer analysis of the environment at that location should be based on camera altitude profiles and imagery data, as acoustic resolution is too coarse. Multiple camera tows at the same locations will help to build a strong dataset to monitor inter-annual changes, whilst comparisons of bathymetry-derived variables between different stations and how they relate to presence or not-presence of Annex I Reef can help to identify statistically recurring properties that influence the groupings of different reef types.

4.2 Biological aspects of the Annex I Reef

4.2.1 Structure and distribution of communities

Analysis of reef epifauna detected very high local variability in epifauna coverage, number of taxa and community composition. In this sense the results are similar to the findings of the community analysis by Barrio-Froján *et al*. (2019) on a dataset combining video and still imagery acquired in 2006, 2012 and 2013. They highlighted the fine scale heterogeneity in assemblage composition observed across a mosaic of substrate types. Their investigation found no links between the environmental variables and the communities observed, other than a subtle west-east gradient in assemblages and taxon richness. This study, on the other hand, determined that both community structure and total epifauna coverage were affected by the availability and type of hard substrata (flat bedrock, boulders, flat cobble, and various mixtures of bedrock, boulders and cobble), the fine scale topography of the reef and the location of the transect on the bottom, top or mid-slope of the larger reef structure. The explanatory power of the environmental variables in the multivariate analysis was very low, meaning the main drivers of community structure and distribution were not captured in the analysis, at least not at the correct spatial resolution. In addition to the stochastic variability stemming from natural heterogeneity, the environmental variables are likely still represented at too coarse a scale. The links between the environmental variables and total epifauna cover were stronger.

There was no statistically significant difference between communities or taxon richness between cobble and bedrock reef. Both reef categories contained transects with varying structural complexity and slope characteristics.

Our analysis benefited from the rationalisation of sampling units and hence reduced noise both within sample and between samples with similar biological and environmental attributes. The way the imagery data were treated and collated before statistical analysis, by:

(1) increasing the size of the sampling unit through pooling of consecutive images,
(2) keeping samples within continuous habitat patches (determined by video segment), and
3) ensuring similar size of each sampling unit greatly reduced the available data from 82 to 36 stations, but also afforded us a better signal to noise ratio than the dataset used previously.

We note that the survey design was not originally intended for the analysis used in this report and the data was not collected using a protocol geared towards pooling images in consistent habitat patches. However, single still images are not fully representative of a reef habitat, and neither are the whole drop camera tows, which in a location like Wight-Barfleur

Reef almost always cover multiple habitats. Consequently, the data was subsampled to fit the pooled analysis strategy. This limitation ultimately reduced the number of transects (habitat segments) and stations with the minimum required number of stills. A more targeted sampling strategy, including the various types of reef and topography, with a good coverage of still images within a habitat segment would provide a more robust baseline for future monitoring. In the current imagery, the video segments themselves could provide better coverage, but would require splitting into segments of consistent quality, and known area cover within an acceptable altitude range.

Taxonomic identification also proved challenging at Wight-Barfleur Reef. Partly the difficulties in identifying taxa to species, or even genus or family, were due to low pixel resolution of slightly out-of-focus images and partly to the high diversity encountered at the site and consequent difficulty assigning specific taxonomic names to otherwise distinguishable units. This, again, mirrored the experience of Barrio-Froján *et al*. (2019), who found some taxa could only be identified to phylum, whilst others were identified to species. The discrepancy in taxonomic level used in identification leads to the use of non-exclusive categorisation of taxonomic units in analyses, which give every taxon the same weight regardless of the nested taxonomic scale and can lead to spurious results. The dataset used by Barrio-Froján *et al*. (2019), containing the presence / absence of 214 individual taxa, formed 30 statistically different groups (SIMPROF clustering). Such a large number of groups is likely an artefact of the taxonomic detail in the source datasets they used (many taxa observed only once or twice), and they determined the main difference between groups was the source of the dataset. To avoid the same problems, the multivariate and species richness analyses in this study were conducted using taxon matrices that were truncated to a modified version of the CATAMI standardised vocabulary for identifying benthic biota and substrata from underwater imagery (Althaus *et al*. 2015).

The CATAMI categories ensure taxonomic identification on a much more equal taxonomic level, by combining Phyla and Class level taxonomy with visually distinguishable attributes like morphotypes. It also standardises the taxonomic categories used making analysis more repeatable. The higher-level taxonomy combined with specific body forms is also potentially more related to function making diversity estimates using CATAMI categories more likely to reflect structural differences in communities. Highlighting the more obvious differences between communities identified at a coarser taxonomic, more functional level, avoids the unduly high influence of infrequent observations of individual species in a species poor taxon matrix.

The epifaunal communities at Wight-Barfleur Reef form a continuum of increasing diversity and abundance of assemblages from flat cobble reef to structurally complex high relief reef. Although seven statistically significant community clusters were found, an investigation of their component fauna and environmental conditions shows a gradual change in the species composition and abundance through a continuum, with large overlap between the more similar groups. All the groups include variations of typical rocky reef sessile epifauna with different proportions of sponges, ascidians, anthozoans, hard and soft bryozoans and hydrozoans. The clearest differences between cluster groups were in the presence of; Foliaceus soft bryozoans (Flustrids) in just one cluster group, Solitary attached stony corals (Caryophyllids) abundant in the two cluster groups with most available hard substrata and located at the highest slope position on the reef, and the diversity of sponge morphotypes, which increased with increasing structural complexity of the reef. The site is, in general, incredibly diverse with numerous examples of sponges of all morphotypes. Although it was not possible to assign species or even type-species for most taxa, made more challenging by the low photo quality, 12 different colour/texture varieties of encrusting sponges alone were distinguishable in the full set of still images. Mobile fauna included true crabs, spider crabs and nut crabs, numerous gastropods, starfish, ophiuroids and the occasional feather star.

No NIS or OSPAR Threatened and/or Declining Species and Habitats were observed at Wight-Barfleur. Although the low taxonomic detail must be considered when assessing the veracity their recorded absence.

4.2.2 Potential metrics and indicators for monitoring

Community

The fine scale spatial variability makes monitoring the site a challenge. Change in community structure is unlikely to be an efficient method of detecting change and does not meet any of the criteria for indicators laid out in Section 2.3.6. No individual taxa were found which would act as effective indicator species for the site. There is a high diversity of sponges of all morphotypes present. Using sampling units with a good spatial coverage over a small distance and accounting for the local environmental setting would ensure meeting the sensitivity, accuracy and simplicity criteria for indicators. The body of research currently underway to establish the indicator will assess its specificity and responsiveness. A more detailed analysis of the taxa making up the morphotypes could be done with re-analysis of specified good quality images from all the existing surveys, to establish how well morphotypes represent more detailed taxonomic categories, and how these relate to the fine scale variability in topography and substrata.

Other potential indicators incorporating community data, suitable for Wight-Barfleur Reef, could be developed through research into the responsiveness and specificity of functional groups or growth forms that can be observed and enumerated without detailed taxonomic identification. Rock dredges would also give more information about the diversity within the morphological groups distinguishable in images. However, non-destructive sampling is preferable for long-term monitoring to avoid damage to the reef ecosystem.

Total epifauna coverage

Total epifauna coverage was also investigated, with the view of assessing its suitability as an indicator of change. Total faunal coverage could act as an indicator of the reef's capability to provide the functional ecosystem service of habitat provision. Whilst the physical reef structure itself provides habitat, sessile fauna add three-dimensional structure, providing attachment surface and shelter for species ranging from bacteria to fish. Total faunal coverage meets the simplicity and spatial applicability criteria but, again, varies at a fine spatial scale in accordance with the mosaic of substrata and reef topography, causing low accuracy and, consequently, sensitivity of estimates. Accounting for the variability resulting from environmental setting would again contribute to alleviating the problem. The level of fragmentation in available substrata may also play a role. A more substantial issue with coverage, which compounds with total cover, is the very subjective nature of the estimates. Subjectivity, with the added difficulty of estimating coverage of a three-dimensional surface, makes recorded values inherently very variable and explains the lack of power indicated by the post-hoc power analysis. If coverage of fauna were to be considered as an indicator of change, further examination is needed into the way coverage is estimated. In the current study, epifauna coverage was extracted from 5 m segments of video footage. The large sample unit obviously adds to imprecision. More comparable and repeatable assessment of coverage would result from; (1) using a standardised set of still images, (2) calculating coverage as a percentage of available hard substrata, (3) enumerating fragmentation (patchiness) of the available substrata, (4) using perpendicular images and only accounting for surface visible directly from above and (5) using digitisation of hard substrata and fauna cover to calculate area. The aforementioned changes would reduce subjectivity but are also labour intensive.

Diversity

The number of taxa is much less variable, and potentially useful as an indicator. In general, number of taxa when extracted from imagery is heavily influenced by image quality and analyst experience and confidence. Using the CATAMI categories avoided both potential issues and emphasised the signal versus noise in taxonomic data. This is reflected in the post-hoc power analysis result, which requires only 18 stations to detect 20% change with 0.8 power (with a significance level of 0.05), indicating high sensitivity and accuracy. Using a set vocabulary of taxa (CATAMI, or a specialised set of morphospecies) for analysts to choose from ensures the same taxonomic scope between years. The higher level morphotype related diversity is also more related to habitat function, conveying more information on potential change in habitat. It is, however, important to consider what taxonomic richness is used to represent. It can be simple, sensitive and accurate and has validity based on studies on infauna, but we also need to consider whether it is responsive to the pressures facing a reef habitat. More research is required to establish what change in taxonomic diversity would mean from a real-world perspective.

Practical recommendations for monitoring epifauna communities at Wight-Barfleur Reef SAC are presented in Section 5.

5 Recommendations for future monitoring

Monitoring the Annex I Reef at the Wight-Barfleur Reef SAC is dependent on visual analysis of the presence and condition of typical fauna. The topographic complexity and high variability at local scale create an environment that is difficult to describe in a repeatable and comprehensive manner. The recommendations below address both issues applying to rocky reef habitats in general, and the special conditions at Wight-Barfleur Reef SAC.

5.1 Operational and survey strategy

- Still images should be the primary source of information, and for analysis purposes should be as standardised as feasibly possible using a drop-frame camera system that is not designed to land on the seafloor. Future monitoring surveys should continue to follow existing imagery guidance (i.e. NMBAQC, Hitchin *et al.* 2015; MESH, Coggan *et al*. 2007) and build on these protocols to optimise the acquisition of imagery data for quantitative monitoring.

- It is important to collect as many still images of good quality with as similar an FOV as possible. For the Wight-Barfleur Reef SAC, a minimum total area of 5 m^2 of seabed images per transect (made up of multiple images with a standardised FOV) was deemed appropriate, although the optimal area may vary depending on the site and feature being investigated. Images with a standard analysed area make it possible to collate a standard number of images to make up a set sample area for each transect.

- The best way to achieve images of equal FOV, outside of systems that are towed or landed on the seafloor, is to ensure image capture at a standardised height above the sea floor. This method standardises the image FOV, and therefore ground resolution and optimal focus settings, at image capture, yielding a fully comparable set of images. It should be noted that this method is logistically challenging in the field due to the need to continually adjust the altitude of the camera unit in response to topographical changes, vessel speed, currents and swell.

- Methods of standardising the length and area analysed along video segments should be further investigated to make the video data more useful for analysis purposes. Video is a good source of counts for conspicuous taxa once the area sampled can be quantified. A quadrat projected onto the ground by fan lasers at capture would allow for counts of individuals from a standardised area. This would be especially advantageous for counts from video segments in rocky terrain, where the camera will be lifted and lowered very frequently to avoid contact with the ground.

- Alternatively, video and images taken at different heights can be post-processed to include a quadrat frame of standardised size prior to analysis. Two pairs of laser scaling devices on the drop camera frame would allow for average FOVs to be calculated and trapezium quadrats to be drawn on each image, to account for the angle of the camera. Such post-processed images will provide a set area cover, but do not account for the variable ground resolution in images of different FOV.

- The above recommendations for imagery standardisation would improve the likelihood of the potential indicator taxa and other metrics fulfilling the ‘Accuracy’ criterion.

- It is imperative that care is taken to assure good quality imagery is being collected in the field. Whilst this may mean that more time is taken up at the start of the survey before data collection begins, this cost is considerably less than the cost of returning from the field with poor quality or unusable images. Camera settings should be adjusted according to conditions on the sea floor, to ensure best achievable focus and lighting, confirmed by test images taken before starting a transect. Training in basic photography skills should be incorporated into standard operating procedures for image acquisition.

- In this report individual still images were pooled into one sampling unit per transect (defined as continuous video segment). Single images of good or adequate quality cover too small an area of the seafloor to act as single samples. Each sample location should be consistent and attempt to minimise within-transect variability. Variability across the site should be captured between transects. Consequently, transects should be kept within depth and substrate type if possible. Shorter transects with more frequent photos would reduce in-transect variability, especially in sites with high local variability such as Wight-Barfleur SAC.

- Transects should be positioned using a stratified approach. Stratification should, however, be based upon detailed topographic and substratum type information, to ensure a consistent sampling target (rock outcrop, area of flat rock) and reduce environmental variation along transects. The high local variability in physical reef conditions makes informed planning of the collection of drop camera imagery especially important, but at the same time challenging. An adaptive strategy allowing direction and length of tow to be determined in the field based on high resolution MBES data and habitat observed along tows can address condition that are highly variable, ensuring accumulation of a set area covered by imagery. The camera tows can be split into comparable sections post-hoc, but planning must ensure coverage of the different reef types (cobble / boulder and bedrock) and bottom, top and sides of reef features.

5.2 Analysis and interpretation

- Due to resolution differences between acoustic and groundtruthing data, a "nested approach" should be pursued for this site, with bathymetry and backscatter used to set the broad topographic scene. Video tow imagery and topographic profiles instead provide a fine scale description of both local physical reef structure and its biological attributes. Both scales should be linked together to construct a final picture of Annex I Reef distribution and provide the best basis for selecting future monitoring stations.

- Whilst the physical structure of the reef itself is not likely to change and does not contribute to condition monitoring, local reef structure needs to be accounted for in describing the biological attributes used to monitor reef condition. Reef elevation and fine scale rugosity, as well as availability of hard substrata, need to be factored into analysis for comparison between time points.

- Current speed and bed stresses could be investigated further to establish a possible link between unstable substrate and Annex I Reef presence.

- Fine sediment mobility in the SAC could be monitored to determine whether it affects the distribution of exposed Annex I Reef.

- Still images are the preferred source of information when imagery has been collected using a drop camera in the challenging conditions of a rocky reef. If data from the video segments are to be included in analysis (e.g. for quantification of epifauna cover or conspicuous indicator taxa), the video should be analysed using a standardised segment, excluding parts of the video which are above a set height above the seabed, to give a quantitative standardised dataset for statistical testing. The standard segment length will in practise be determined by the shortest distance the camera is within range.

- A standard level of taxonomic detail needs to be set for the identification of each taxon observed at the site. Using a standardised species categorisation, such as CATAMI, or morphotype/species where needed will be more informative than a strictly taxonomic identification. At Wight-Barfleur it was not possible to identify taxa to species or genus, and identification was done at the level of distinguishable units. It is important to recognise the limitations of identification from imagery of such species as the flabellate sponges *A. infundibuliformis* versus *P. ventilabrum*, or arborescent sponges *Axinella* spp. vs. *Raspailia* spp, which can only be definitively identified using microscopic comparison of their structure, and confident identification in the field requires tactile information about surface texture. In addition to the standard level agreed upon, taxa can be identified to more detailed level where possible, for use in a site species list, whilst not included in any quantitative analysis.

- Once further improvements in the Epifauna Identification Protocol (EIP) being developed have incorporated lists of taxa (including all levels of possible identification from CATAMI/morphotaxa to species) identifiable from drop camera still imagery accounting for the ground resolution (smallest object reliably identifiable), the EIP should be used as a guide to the level of taxonomic identification.

- For each taxon that will be used in quantitative analysis, a decision should be taken on how it will be enumerated (count vs. percent cover, or a universal enumeration method, such as random point counts or frequency grid) and abundance recorded the same way for each image. Also, it should be considered how the scales used will affect merging of taxa at the truncation stage. The decisions made for the first monitoring event will determine the scale used in all successive surveys. Introducing one standardised measurement unit for all taxa would ensure repeatable, comparable measurements for quantitative analysis. In addition to providing a more inclusive and comprehensive dataset, this would increase the likelihood of the potential indicator taxa fulfilling the OSPAR (2012) ‘Accuracy’ criterion.

- The best dataset for quantitative analysis (a fully quantitative, standardised dataset using robust scientific design) would be achieved by standardising the area of the seafloor analysed in each image, allowing the use of the same number of images for each transect to achieve same sample area.

- Using the CATAMI scheme (or other predetermined list of taxa or functional units) can make comparisons of taxa present more useful for monitoring than using counts of species, which are dependent on image quality and analyst experience and confidence. Further thought needs to go into the purpose of diversity metrics in monitoring to determine which attributes to use to compile the list.

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Appendix 1. Acknowledgments

Wight-Barfleur Reef Special Area of Conservation (SAC) Characterisation Report 2017

Marine Protected Areas (MPA) Monitoring Programme

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Appendix 2. Selection of still images for quantitative analysis

Video and still images acquired using cameras towed on the seafloor have a consistent FOV across the tow and are hence readily applicable to quantitative analysis. However, imagery acquired using a drop-frame camera often consists of video segments and images taken at a wide range of heights above the seafloor, leading to variability both in the FOV and the ground resolution in images. Ground resolution refers to the size of the smallest possible feature of interest that can be detected in the image. Imagery from drop cameras is therefore not comparable across the tow, and consequently not suitable for quantitative analysis. The still images were chosen for analysis of species richness and multivariate community statistics, due to the relative ease of evaluating the area sampled across the tow, in comparison to the video data and, hence, create a semi-standardised quantitative dataset. To extract a subset of still images to achieve a comparable sampled area, first the area of each image was calculated, and consequently a representative and comparable subset of images was selected for each tow.

Image FOV Calculation

FOV (i.e. the area of seabed covered in each image), was calculated from the known distance between laser scale dots using method developed from Wakefield and Genin (1987). Gardline's CountEM software was used to automatically detect the location of the laser dots within the image and these measurements were then used, along with camera view angles, to produce an approximate area. This required both laser dots to be fully visible at the seabed.

The method used is originally designed for use with laser scale lines and it carries several assumptions, not all of which are strictly met. One major assumption, which is not met, is that the camera is directly perpendicular to seafloor. Not meeting this assumption means that area estimates must be treated as very approximate. The calculation method used will ensure consistent, and hence comparable, area estimates across images, but they will all carry the same approximation error. The method assumes that the horizontal and vertical camera FOV angles and the seafloor scale on top and bottom edges are known, which in this case had to be estimated from the camera angle whilst only one pair of lasers was used. It is further assumed that no level of zoom has been used and the camera roll angle is zero. It is also assumed that the camera lens has no distortion of size towards the edges. Any inconsistencies in the relative angle of the lasers to the plane of orientation of the camera due to them being mounted on separate platforms will introduce further error (Gardline 2017).

Given the assumptions described above, the approximate height and width of the image were calculated from the difference in separation between the laser dots in pixel and the known physical distance of the lasers. The calculation uses the known acceptance angles of the camera to calculate the distance of the camera from the seafloor, and consequently the height of in the image. This allows the area of seafloor visible to be coarsely estimated (Gardline 2017).

The automatic calculation was checked by the image analyst and erroneous values were re-calculated by manually identifying the relevant laser dot features within the photograph (Gardline 2017).

Selection of images for quality and consistency

The range of FOV in images was plotted for each habitat type, with the analyst defined Quality Score (Excellent / Good / Poor / Very poor, as defined in the NMBAQC guidelines, Turner *et al*., 2016) to gauge the appropriate FOV range for quantitative analysis (Figure 30). Excellent quality images were mainly below a FOV of 0.5 m^2, whereas images with a FOV above 0.7 m^2 tended to be of poor quality. Better quality images with a small FOV number contain greater taxonomic diversity due to the smaller number of uncertain identifications in well-lit, high-resolution images. Most images were in the 0.25–0.75 m^2 FOV range.

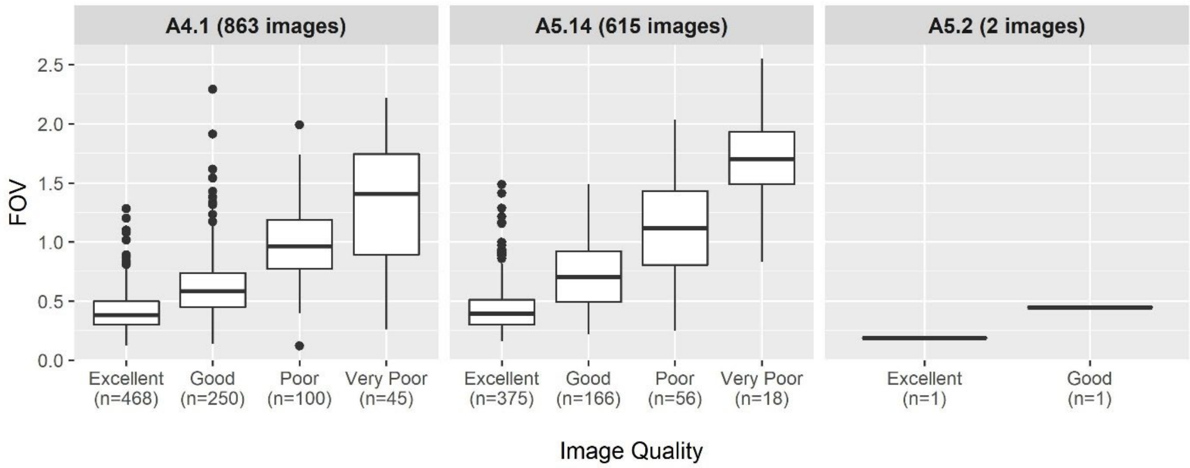

Figure 30. Range of image FOV (m^2) across broadscale habitats for each image quality class (assigned by the analyst during image processing).

The final image quality parameter threshold (FOV of 0.6 m^2) was chosen to optimise both the number of sampling stations with a sufficient number of images and taxonomic detail retained (see Table 18).

Only two images fell into the ‘A5.2 Sublittoral sand’ habitat type and were removed from analysis.

Table 18. The number of stations with a set number of images retained after applying various FOV thresholds.

	FOV 0.6 m^2	FOV 0.5 m^2	FOV 0.4 m^2
No. Images	**No. Stations**	**No. Stations**	**No. Stations**
1	82	82	80
5	75	67	52
6	70	60	39
7	66	56	34
8	57	49	29
10	48	32	17

Semi-quantitative data subset

Species accumulation curves per reef type (‘Stony reef’ / ‘Bedrock reef’) in each video segment were computed using the filtered dataset. A plot of species accumulation with increasing area covered by images were used to determine the standard sample area per transect to include in the final dataset (Figure 31). The species accumulation curves were calculated in R (v. 3.3.2, R Core Team 2017) using the *accumcomp* function in the 'BiodiversityR' package (Kindt & Coe 2005). The species accumulation curves indicated that a sampled area of approximately 4–5 m^2 was required to sufficiently describe diversity along a transect. Very few transects had enough images to achieve this area. To maintain a sufficient number of samples for analysis, a standard area range of 1–2 m^2 was selected, to minimise area dependence in quantitative estimates. Images for each reef type in each segment were randomly subsampled until the maximum area of 2 m^2 was achieved for a sample. Sample units that did not reach a minimum area of 1 m^2 were rejected. A total of 43 samples (9 'Not reef', 6 'Bedrock reef' and 28 'Stony reef') were included in the final dataset.

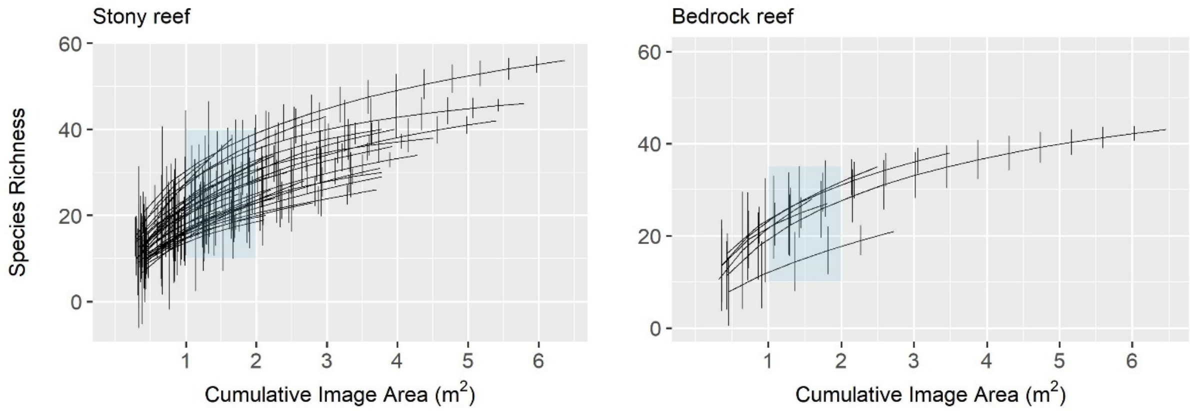

Figure 31. Species accumulation curves from images by video segment, with estimated confidence intervals (2 x st. dev.). The selected standard sample cumulative area range is highlighted in blue.

The final taxon matrix was truncated according to the protocols laid out in the following section (Appendix 3). SACFOR abundance from individual images in each transect were pooled into one abundance value per taxon by assigning each category a numeric value from 1–6 (Rare – Superabundant) and taking the median numeric SACFOR value across all included images. Percent cover was aggregated as a mean across the images in the sample, whilst counts were collated as a density (individuals/m^2) by dividing the total number observed in the images comprising each sample by its total FOV.

Appendix 3. Epifauna data truncation

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

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

Details of the data preparation and truncation protocols applied to the epifaunal dataset acquired at Wight-Barfleur Reef SAC ahead of the analyses reported here are provided below.

Taxa were recorded over many taxonomic levels from phylum to species. To enable further separation of taxa only confidently identified to a high taxonomic level, each morphologically distinct entity was identified to the lowest taxonomic level possible and denoted by a unique identifier between entries at the same level (e.g. Porifera A, Porifera B, Mollusca – Gastropoda A, Mollusca – Gastropoda B, Table 19). Initially, all assigned taxon names were collated with accompanying counts of occurrences in all still images and video segments, and a subset of images meeting the standard of a maximum FOV of 0.6 m^2 (see Appendix 2), forming a truncation matrix that was used as a basis for decisions.

Taxon names were truncated at two different levels:

1) Morphospecies: Each morphologically distinct species or group of species were kept separate, and where appropriate given the genus/species name of an example species with that morphotype.

2) A modified version of the CATAMI scheme of standardised terminology for annotating benthic substrates and biota in marine imagery (Althaus *et al*. 2015).

The morphospecies approach was used to include the maximum number of separate morphologically distinct groups of individuals to avoid oversimplification of the taxon list. This approach allows more information to be retained in the community matrix, but it maintains the mixed multilevel taxonomic identification structure and places high weight on certain easily distinguishable taxa. The truncation is not easily repeatable without reference to the original image reference collection and a well recorded rationale for each truncation decision, which reflect image quality and analyst confidence in assigning taxonomic certainty.

The taxonomic entries in the raw data were compared to the taxonomic reference collection of example stills, provided by the contractor in support of their identification decisions, to ensure taxon entries were exclusive of others. The consequent epifauna data preparation and truncation into morphospecies followed the steps detailed below:

1.) All fish, cephalopods and eggs were removed.

2.) Taxa occurring in very few images and with uncertain identification were removed from the dataset.

3.) Porifera were reduced to morphotypes (following Turner *et al*. 2016), with accompanying qualifiers used for colour and/or texture to maintain maximum information.

4.) Ascidians were categorised as solitary or colonial and accompanying qualifiers used for colour and/or size.

5.) Large and easily distinguishable taxa identified to species or genus were kept separate, even when other taxa were truncated to a higher taxonomic category, where there was no chance of overlap.

6.) Various taxa with similar morphotypes were merged into morphospecies, with a cf. taxon identifier (e.g. Serpulidae, calcareous worm tubes and tubeworms, all variants of calcareous worm tubes were combined and named 'cf. Serpulidae').

7.) Finely branching hydrozoa were all combined under Hydrozoa – filamentous.

The CATAMI classification scheme was designed to allow imagery from a range of sources (including video and digital stills), with varying resolution, and across marine habitats from shallow waters to abyssal depths to be classified using the same set of consistent identifiers (Althaus *et al*. 2015). The scheme was designed to avoid duplication of categories and to allow all sensing techniques to result in the same classifications, whilst allowing the resolution and quality of imagery to define the level in the hierarchy to be used. The scheme was designed to be flexible enough that it can be modified when new information is presented, but also be stable enough that it can support ongoing use. Changes and additions are allowed but should be clearly documented and related back to earlier categories.

With CATAMI, the data were:

1) Consistently truncated to the lowest level of the scheme.

2) Additional categories were added for nutcrabs and spider crabs, which were both prevalent in the data.

3) Hydrozoa were split into 'branched' (e.g. *Abietinaria* sp.), 'bushy' and 'erect' (e.g. *Tubularia* sp.) categories.

The final truncation table for the still image dataset is provided in Table 19, detailing the truncation decisions and rationales.

Table 19. Epifauna taxon truncation matrix.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Animalia Eggs - A	2	1	Remove	Remove	Removed all eggs
Animalia Eggs - B	4	21	Remove	Remove	
Animalia Eggs - C	2	-	Remove	Remove	
Animalia Eggs - D	-	1	Remove	Remove	
Animalia Eggs - E	1	-	Remove	Remove	
Animalia Eggs - F	-	1	Remove	Remove	
Animalia Indeterminate	4	-	Remove	Remove	Removed various uncertain identifications of taxa that occur in very few images.
Animalia Indeterminate - B	2	-	Remove	Remove	
Animalia Indeterminate - C	2	-	Remove	Remove	
Animalia indeterminate - D	1	-	Remove	Remove	
Animalia Indeterminate - H	8	-	Remove	Remove	
Animalia Indeterminate - L	1	-	Remove	Remove	
Animalia indeterminate - R	-	-	Remove	Remove	
Animalia Indeterminate - S	1	-	Remove	Remove	
Animalia Indeterminate - G	-	1	Remove	Remove	
Animalia Indeterminate - R	-	3	Remove	Remove	
Indeterminate Tube - A	-	-	Remove	Remove	
Annelida - Indeterminate A	1	-	Remove	Remove	
Animalia Indeterminate - N	16	-	Animalia Indeterminate - N	Remove	Kept separate as consistently identified in more than ten high quality images, not similar to anything else identified.
Animalia Indeterminate - P	10	-	Filograna implexa cf	Remove	Merged with Filograna, looks very similar in inspected photos.
Animalia Indeterminate - Q	12	-	Animalia Indeterminate - Q	Remove	Kept separate as consistently identified in more than ten high quality images, not similar to anything else identified.
Indeterminate Turf A	586	-	Indeterminate Turf A	Faunal turf	Kept separate as consistently identified in more than ten high quality images, not similar to anything else identified.
Indeterminate Turf B	26	-	Indeterminate Turf B	Faunal turf	
Indeterminate Turf E	25	61	Indeterminate turf E	Faunal turf	
Annelida - *Lanice conchilega*	2	-	Remove	Remove	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Annelida - Sabellida B	2	-	Remove	Remove	Removed from dataset, occur in very few images, not appendable to higher taxon.
Annelida - Sabellida C	2	-	Remove	Remove	
Annelida - Tube	1	-	Remove	Remove	
Annelida - Sabellida A	-	169	Remove	Tubeworms	Kept for video segments - regularly observed.
Annelida - Bispira	11	-	Sabellida - Bispira cf	Tubeworms	Merged with Sabellida, light coloured fan worms in rock crevices, ID reduced to cf.
Annelida - Sabellida	48	-	Sabellida - Bispira cf	Tubeworms	Merged with Bispira, light coloured fan worms in rock crevices.
Annelida - *Filograna implexa*	34	-	*Filograna implexa* cf	Tubeworms	Merged with Animalia Indeterminate - P, look very similar in inspected photos, ID reduced to cf.
Annelida - Polychaete tube	57	-	Serpulidae cf	Tubeworms	Merged with Serpulidae, calcareous worm tubes, ID reduced to cf.
Annelida - Serpulidae	589	-	Serpulidae cf	Tubeworms	Merged with polychaete tube, calcareous worm tube.
Annelida - Sabellaria	92	-	Sabellaria	Tubeworms	Consistently identified in more than ten high quality images, not similar to anything else identified.
Arthropoda - *Cancer pagurus*	1	-	Remove	Remove	Removed various uncertain identifications of taxa that occur in very few images.
Arthropoda - *Homarus gammarus*	-	-	Remove	Remove	
Arthropoda - Majoidea B	3	-	Remove	Remove	
Arthropoda - Munididae	-	-	Remove	Remove	
Arthropoda - Munididae	-	-	Remove	Remove	
Arthropoda - Cirripedia	76	-	Cirripedia	Barnacles	Kept separate as consistently identified in more than ten high quality images, not similar to anything else identified.
Arthropoda - Brachyura	18	-	Ebalia cf	Nutcrabs	Merged Brachyura with Majoidea C, all seem to refer to small nutcrabs, reclassified as Ebalia cf.
Arthropoda - Majoidea C	13	-	Ebalia cf	Nutcrabs	
Arthropoda - Majoidea	26	-	Macropodia/ Inachus cf	Spider crabs	Joined Majoidea and Majoidea D, which look like Macropodia spp. and Inachus spp., respectively, but hard to be sure about ID, so combined to small spider crabs.
Arthropoda - Majoidea D	22	-	Macropodia /Inachus cf	Spider crabs	
Arthropoda - Paguridae	15	-	Paguridae	Hermit crabs	Kept hermit crabs as their own group, easy to ID and not included in any of the other arthropod taxon categories used.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Arthropoda - A	-	1	Remove	Remove	Only observed in video segments.
Arthropoda - Amphipoda A	-	1	Remove	Remove	
Arthropoda - Brachyura A	-	29	Remove	True crabs	
Arthropoda - Brachyura B	-	1	Remove	True crabs	
Arthropoda - Brachyura C	-	1	Remove	True crabs	
Arthropoda - Majoidea A	-	66	Remove	Spider crabs	
Arthropoda - Majoidea Indeterminate	-	7	Remove	Spider crabs	
Bryozoa - B	1	-	Remove	Remove	Removing various uncertain identifications of taxa that occur in very few images.
Bryozoa - E	1	-	Remove	Remove	
Bryozoa - *Alcyonidium diaphanum*	142	-	*Alcyonidium diaphanum*	Dendroid soft bryozoa	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Bryozoa - Flustridae	278	-	Flustridae	Dendroid soft bryozoa	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Bryozoa - C	7	-	Bryozoa B	Foliaceous soft bryozoa	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Bryozoa - Horneridae	54	-	Porella sp.	Branching hard bryozoa	Looks like Porella. Horneridae not really known in the English Channel.
Bryozoa - *Pentapora foliacea*	87	-	*Pentapora foliacea*	Massive hard bryozoa	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Chordata - Ammodytidae	1	-	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Chordata - Ascidiacea A	-	-	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Chordata - Ascidiacea B	398	-	Solitary red ascidian	Unstalked solitary ascidean	Grouped the solitary larger ascidians by colour morph.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Chordata - Ascidiacea M	26	-	Solitary pink ascidian	Unstalked solitary ascidean	
Chordata - Ascidiacea D	69	-	Solitary white ascidian	Unstalked solitary ascidean	
Chordata - Ascidiacea E	393	-	Solitary white ascidian	Unstalked solitary ascidean	
Chordata - Ascidiacea H	85	-	Solitary white ascidian	Unstalked solitary ascidean	
Chordata - Ascidiacea L	51	-	Solitary white ascidian	Unstalked solitary ascidean	
Porifera - AF	254	-	Solitary brown ascidian	Unstalked solitary ascidean	This is identified as porifera but looks more like a dirt covered ascidian.
Chordata - Ascidiacea G	36	-	Colonial orange ascidian	Unstalked colonial ascidean	Grouped the colonial ascidians by colour morph. Some may still be colour varieties of the same ascidian.
Chordata - Ascidiacea C	77	-	Colonial yellow ascidian	Unstalked colonial ascidean	
Chordata - Ascidiacea J	31	-	Colonial red ascidian	Unstalked colonial ascidean	
Chordata - Ascidiacea F	86	-	Colonial brown ascidian	Unstalked colonial ascidean	
Chordata - Ascidiacea N	24	-	Colonial brown ascidian	Unstalked colonial ascidean	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Chordata - Ascidiacea O	3	-	Colonial white ascidian	Unstalked colonial ascidean	
Chordata - Ascidiacea K	17	-	Colonial translucent ascidian	Unstalked colonial ascidean	
Chordata - Didemnidae	19	-	Didemnidae	Unstalked colonial ascidean	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Chordata - Actinopterygii	3	-	Remove	Remove	Removed all fish.
Chordata - Elasmobranchii egg case	1	-	Remove	Remove	
Chordata - Gadidae (Juv)	-	-	Remove	Remove	
Chordata - *Labrus mixtus*	2	-	Remove	Remove	
Chordata - *Melanogrammus aeglefinus*	1	-	Remove	Remove	
Chordata - Mustelus	1	-	Remove	Remove	
Chordata - *Scyliorhinus canicula*	1	-	Remove	Remove	
Chordata - Triglidae	1	-	Remove	Remove	
Chordata - Trisopterus sp.	4	63	Remove	Remove	
Chordata - Actinopterygii B	-	3	Remove	Remove	
Chordata - Actinopterygii C	-	5	Remove	Remove	
Chordata - Actinopterygii indeterminate	-	41	Remove	Remove	
Chordata - *Chelidonichthys cuculus*	-	3	Remove	Remove	
Chordata - *Chirolophis ascanii*	-	9	Remove	Remove	
Chordata - *Ctenolabrus rupestris*	-	9	Remove	Remove	
Chordata - Gadidae	-	6	Remove	Remove	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Chordata - Labridae A	-	1	Remove	Remove	
Chordata - Labridae B	-	2	Remove	Remove	
Chordata - Labridae C	-	1	Remove	Remove	
Chordata - Labridae D	-	1	Remove	Remove	
Chordata - Lotidae	-	1	Remove	Remove	
Chordata - Pleuronectiformes	-	3	Remove	Remove	
Chordata - Scorpaeniformes A	-	1	Remove	Remove	
Chordata - Scorpaeniformes B	-	3	Remove	Remove	
Chordata - Zoarcidei	-	2	Remove	Remove	
Cnidaria - Anthozoa B	4	7	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Cnidaria - Anthozoa A	2	-	Remove	Remove	
Cnidaria - Anthozoa C	3	-	Remove	Remove	
Cnidaria - Anthozoa D	2	-	Remove	Remove	
Cnidaria - Anthozoa E	1	-	Remove	Remove	
Cnidaria - Actiniaria H	1	-	Remove	Remove	Removed various uncertain identifications of taxa that occur in very few images, or are too high taxonomic level to be useful, anemones kept in the CATAMI group.
Cnidaria - Actiniaria I	1	-	Remove	Remove	
Cnidaria - Actiniaria G	6	-	Remove	Other anemones	
Cnidaria - Actiniaria indeterminate	58	-	Remove	Other anemones	
Cnidaria - Actiniaria A	64	-	Actiniaria A	Other anemones	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Cnidaria - Sagartiidae A	81	73	Sagartiidae	Other anemones	Grouped two colour morphs together.
Cnidaria - Sagartiidae B	104	286	Sagartiidae	Other anemones	
Cnidaria - Actiniaria F	17	-	Sagartiidae	Other anemones	Similar to the Sagartiidae, combined.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Cnidaria - Urticina	112	-	Urticina spp.	Other anemones	Combined Urticina spp. to genus.
Cnidaria - *Urticina felina*	22	-	Urticina spp.	Other anemones	
Cnidaria - Actiniaria B	50	-	Actinothoe cf.	Other anemones	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Cnidaria - Actiniaria C	13	-	Actiniaria small fine tentacled	Other anemones	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Cnidaria - *Alcyonium digitatum*	170	-	*Alcyonium digitatum*	Massive soft corals	Distinct large species.
Cnidaria - Scleractinia	57	-	Caryophyllia cf	Solitary attached stony corals	Distinct large species.
Cnidaria - Zoantharia B	2	2	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Cnidaria - Zoantharia A	74	11	Colonial anemones	Colonial anemones	Combined Zoantharia A and Corallimorpharia A - too similar to separate. Often dubious ID in images. Renamed to colonial anemones.
Cnidaria - Corallimorpharia A	16	-	Colonial anemones	Colonial anemones	
Cnidaria - Hydrozoa A	-	-	Remove	Remove	Removed various uncertain identifications of taxa that occur in very few images.
Cnidaria - Hydrozoa D	-	-	Remove	Remove	
Cnidaria - Hydrozoa I	3	-	Remove	Remove	
Cnidaria - Hydrozoa P	2	-	Remove	Remove	
Cnidaria - Hydrozoa S	-	2	Remove	Remove	
Cnidaria - cf. *Polyplumaria flabellata*	-	7	cf. Nemertesia	Hydrozoa erect	
Cnidaria - cf *Polyplumaria flabellata*	31	-	cf. Nemertesia	Hydrozoa erect	cf *Polyplumaria flabellata* and cf. Nemertesia are the same thing - potentially another species altogether, but distinct in morphotype. Other hydrozoa with similar morphotype also included.
Cnidaria - cf. Nemertesia	400	-	cf. Nemertesia	Hydrozoa erect	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Cnidaria - Hydrozoa C	3	-	cf. Nemertesia	Hydrozoa erect	
Cnidaria - Hydrozoa F	32	-	cf. Nemertesia	Hydrozoa erect	
Cnidaria - cf *Sertularia argentea/cupressina*	29	59	cf *Sertularia argentea/ cupressina*	Hydrozoa erect	ID not certain, but distinct morphotype.
Cnidaria - cf. *Tubularia indivisa*	31	-	cf. *Tubularia indivisa*	Hydrozoa erect	*Tubularia indivisa* and similar stringy hydrozoan combined.
Cnidaria - Hydrozoa M	23	-	cf. *Tubularia indivisa*	Hydrozoa erect	
Cnidaria - Hydrozoa H	10	-	Hydrozoa - stringy	Hydrozoa erect	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Cnidaria - Hydrozoa B	2	-	Hydrozoa - filamentous	Hydrozoa bushy	All finely branching thin filamentous and bushy growth forms of hydroid.
Cnidaria - Hydrozoa E	31	-	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa G	11	-	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa J	11	5	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa K	1	-	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa L	13	11	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa N	16	44	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa O	10	-	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa R	16	6	Hydrozoa - filamentous	Hydrozoa bushy	
Cnidaria - Hydrozoa indeterminate	64	617	Hydrozoa - filamentous	Hydrozoa bushy	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Cnidaria - hydrozoa Q	13	2	cf. Abietinaria	Hydrozoa branching	Combined all taxa of the same morphotype. Species name only as a guide to distinct morphotype, not ID.
Cnidaria - Hydrozoa T	73	-	cf. Abietinaria	Hydrozoa branching	
Cnidaria - cf. *Diphasia alata*	-	67	Remove	Hydrozoa branching	Only observed in video segments.
Echinodermata - Echinoidea	1	-	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Echinodermata - Echinoidea A	-	-	Remove	Remove	
Echinodermata - Holothuria	1	-	Remove	Remove	
Echinodermata - Holothuria B	1	-	Remove	Remove	
Echinodermata - Antedonidae A	7	7	Antedonidae	Feather stars	Distinct large species.
Echinodermata - Asterinidae	2	-	Asteroidea	Sea stars	Combined to starfish morphotype.
Echinodermata - Asteroidea	78	-	Asteroidea	Sea stars	
Echinodermata - *Crossaster papposus*	16	-	*Crossaster papposus*	Sea stars	Distinct large species.
Echinodermata - Ophiuroidea	71	-	Ophiuroidea	Brittlestars	Combining to brittle stars.
Echinodermata - Ophiuroidea Bed	71	91	Ophiuroidea Bed	Brittlestars	
Echinodermata - *Asterias rubens*	-	2	Remove	Sea stars	Only observed in video segments.
Mollusca - Loliginidae A	1	-	Remove	Remove	Removed cephalopods.
Mollusca - Sepiidae	1	-	Remove	Remove	
Mollusca - Sepiolidae	-	1	Remove	Remove	
Mollusca - Bivalvia A	9	5	Remove	Bivalves	Removed all bivalves, apart from scallops from taxa, cannot tell if they are alive. Included as one category in CATAMI.
Mollusca - Bivalvia B	2	3	Remove	Bivalves	
Mollusca - Bivalvia C	20	10	Remove	Bivalves	
Mollusca - Bivalvia D	2	-	Remove	Bivalves	
Mollusca - Bivalvia E	5	1	Remove	Bivalves	
Mollusca - Bivalvia F	5	2	Remove	Bivalves	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Mollusca - Bivalvia G	8	-	Remove	Bivalves	
Mollusca - Bivalvia H	1	1	Remove	Bivalves	
Mollusca - Bivalvia I	4	2	Remove	Bivalves	
Mollusca - Bivalvia J	1	-	Remove	Bivalves	
Mollusca - Bivalvia K	1	-	Remove	Bivalves	
Mollusca - Fissurellidae	1	-	Remove	Bivalves	
Mollusca - *Trivia arctica*	2	-	Remove	Bivalves	
Mollusca - Veneridae	1	-	Remove	Bivalves	
Mollusca - Pectinidae	45	-	Pectinidae	Bivalves	Distinct large species.
Mollusca - Gastropoda B	4	-	Remove	Gastropods	Removed all small unidentified gastropods from main data, kept in as gastropods in CATAMI.
Mollusca - Gastropoda C	1	-	Remove	Gastropods	
Mollusca - Turritellidae	1	-	Remove	Gastropods	
Mollusca - Buccinidae	67	75	Buccinidae	Gastropods	Distinct large species.
Mollusca - Calliostoma sp	263	491	Calliostoma sp	Gastropods	Distinct morphotype.
Mollusca - Gastropoda	9	-	Opistobranchia	Gastropods	Distinct morphotype.
Mollusca - Nudibranchia	16	-	Nudibranchia	Gastropods	Combined all nudibranchs, as only single individuals of other than pink ones. All included in gastropods in CATAMI.
Mollusca - Nudibranchia B	1	-	Nudibranchia	Gastropods	
Mollusca - Nudibranchia C	1	-	Nudibranchia	Gastropods	
Mollusca - Nudibranchia D	1	-	Nudibranchia	Gastropods	
Porifera - A	717	1390	Orange encrusting	Thin encrusting sponge	Grouped encrusting sponges by colour and morphology.
Porifera - AC	9	-	Orange encrusting	Thin encrusting sponge	
Porifera - AH	10	-	Pink spotty encrusting	Thick encrusting sponge	
Porifera - AA	470	527	Green encrusting	Thick encrusting sponge	

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Porifera - B	168	-	White encrusting	Thick encrusting sponge	
Porifera - C	391	-	White encrusting	Thick encrusting sponge	
Porifera - Z	21	-	White encrusting	Thick encrusting sponge	
Porifera - E	556	-	Yellow nobbly encrusting	Thin encrusting sponge	
Porifera - K	191	-	Red encrusting	Thin encrusting sponge	
Porifera - L	149	-	Pink encrusting	Thick encrusting sponge	
Porifera - P	66	44	Small pink	Thick encrusting sponge	
Porifera - Myxillidae A	22	15	Myxillidae	Thick encrusting sponge	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Hymedesmia	18	-	Hymedesmia	Thick encrusting sponge	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - *Hymedesmia paupertas*	4	-	Hymedesmia	Thick encrusting sponge	
Porifera - I	234	196	cf. Hemimycale	Thick encrusting sponge	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Porifera - U	61	-	cf Dercitus	Thin encrusting sponge	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AJ	12	13	cf. Raspailia	Erect branching sponges	Kept separate. Distinct large species consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Axinellidae	20	361	Axinellidae	Erect branching sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - cf *Dysidea fragillis*	245	98	Dysidea	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - H	81	-	Tethya cf	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - V	4	-	cf. Suberites	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AB	20	-	White globular	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - R	76	-	Small brown globular	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - W	15	-	Red bobble	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AP	4	-	Yellow burrowing	Bioeroding crust sponges	Combined Animalia Indeterminate - A with the burrowing sponge, based on images in which thy occur.
Animalia Indeterminate - A	18	-	Yellow burrowing	Bioeroding crust sponges	
Porifera - AK	3	-	White massive	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Porifera - AO	12	-	Yellow nobbly	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - D	262	723	Yellow scrunched	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Cliona celata	7	-	cf. Cliona celata	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AE	12	-	cf. Cliona celata	Massive simple sponges	
Porifera - cf Mycale lingua	21	10	Mycale	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - *Pachymatisma johnstonia*	97	-	*Pachymatisma johnstonia*	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - N	151	171	Brown lobed	Massive simple sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AL	1	-	Yellow papillate	Massive cryptic sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Polymastia A	51	221	Polymastia cf. boletiformis	Massive ball sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Polymastia B	16	-	Polymastia cf. penicillus	Massive cryptic sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - G	30	-	White papillate	Massive cryptic sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.

Name in raw data	< 0.6	Seg.	Truncated	CATAMI	Notes
Porifera - cf *Axinella infundibuliformis*	4	22	Axinella/ Phakellia	Cup sponges	Combined *Axinella infundibuliformis* and Phakellia sp. together. They are not consistently distinguishable from images.
Porifera - Phakellia	11	-	Axinella/ Phakellia	Cup sponges	
Porifera - O	109	-	Yellow branching	Erect palmate sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - Sycon	25	-	Sycon	Tube-like sponges	Kept separate. Distinct morphotype consistently identified in more than ten high quality images, not similar to anything else identified.
Porifera - AQ	1	-	Remove	Remove	Removed uncertain identifications of taxa that occur in very few images.
Porifera - AG	8	-	Remove	Remove	
Porifera - cf. Geodiidae	2	-	Remove	Remove	
Porifera - Indeterminate	3	-	Remove	Remove	

Appendix 4. Marine litter categories

Table 20. Categories and sub-categories of litter items for Sea Floor from the OSPAR/ICES/IBTS for North-East Atlantic and Baltic. Guidance on Monitoring of Marine Litter in European Seas, a guidance document within the Common Implementation Strategy for the Marine Strategy Framework Directive, MSFD Technical Subgroup on Marine Litter 2013.

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

Related size categories
- A: ≤ 5*5 cm = 25 cm^2
- B: ≤ 10*10 cm = 100 cm^2
- C: ≤ 20*20 cm = 400 cm^2
- D: ≤ 50*50 cm = 2,500 cm^2
- E: ≤ 100*100 cm = 10,000 cm^2
- F: ≥ 100*100 cm = 10,000 cm^2

Appendix 5. Non-indigenous species lists

Table 21. 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
Crassostrea angulata	Present	*Celtodoryx ciocalyptoides*	Horizon
Crassostrea gigas	Present	*Chama sp.*	Horizon
Crepidula fornicata	Present	*Dendostrea frons*	Horizon
Diadumene lineata	Present	*Gracilaria vermiculophylla*	Horizon
Didemnum vexillum	Present	*Hemigrapsus penicillatus*	Horizon
Dyspanopeus sayi	Present	*Hemigrapsus sanguineus*	Horizon
Ensis directus	Present	*Hemigrapsus takanoi*	Horizon
Eriocheir sinensis	Present	*Megabalanus coccopoma*	Horizon
Ficopomatus enigmaticus	Present	*Megabalanus zebra*	Horizon
Grateloupia doryphora	Present	*Mizuhopecten yessoensis*	Horizon
Grateloupia turuturu	Present	*Mnemiopsis leidyi*	Horizon
Hesperibalanus fallax	Present	*Ocenebra inornata*	Horizon
Heterosigma akashiwo	Present	*Paralithodes camtschaticus*	Horizon
Homarus americanus	Present	*Polysiphonia subtilissima*	Horizon
Rapana venosa	Present	*Pseudochattonella verruculosa*	Horizon
Sargassum muticum	Present	*Rhopilema nomadica*	Horizon
Schizoporella japonica	Present	*Telmatogeton japonicus*	Horizon
Spartina townsendii var. anglica	Present		
Styela clava	Present		
Undaria pinnatifida	Present		
Urosalpinx cinerea	Present		
Watersipora subatra	Present		

Table 22. 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 (2017)
Thalassiosira punctigera	
Thalassiosira tealata	
Coscinodiscus wailesii	
Odontella sinensis	
Pleurosigma simonsenii	
Grateloupia doryphora	
Grateloupia filicina var. luxurians	*Grateloupia subpectinata*
Pikea californica	
Agardhiella subulata	
Solieria chordalis	
Antithamnionella spirographidis	
Antithamnionella ternifolia	
Polysiphonia harveyi	*Neosiphonia harveyi*
Colpomenia peregrine	
Codium fragile subsp. atlanticum	
Codium fragile subsp. tomentosoides	*Codium fragile* subsp. *atlanticum*
Gonionemus vertens	
Clavopsella navis	*Pachycordyle navis*
Anguillicoloides crassus	
Goniadella gracilis	
Marenzelleria viridis	
Clymenella torquata	
Hydroides dianthus	
Hydroides ezoensis	
Janua brasiliensis	
Pileolaria berkeleyana	
Ammothea hilgendorfi	
Elminius modestus	*Austrominius modestus*
Eusarsiella zostericola	
Corophium sextonae	
Rhithropanopeus harrissii	

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

Appendix 6. GIS derivatives and segmentation process

Table 23. GIS derivatives.

Derivative	Description
Bathymetric Position Index (BPI) 25 / 10 / 5	Derived from bathymetry, vertical position of cell relative to neighbourhood (identifies topographic peaks and troughs). Calculated with three neighbourhood sizes of 25, 10 and 5 cells to capture topographical elevation at different spatial scales.
Negative† and positive openness	Derived from bathymetry. It expresses 'the degree of dominance or enclosure of a location on an irregular surface'. To determine the openness value for a specific location, profiles along at least eight directions (N, NW, W, SW, S, SE, E, NE) are derived from a given DEM within a defined radial distance. Starting from the raster element under consideration, the largest possible zenith (α) or nadir (β) angle along each profile is determined. The mean value of all zenith angles equals the positive openness, whilst the mean nadir value designates negative openness. Perfectly flat surfaces, regardless of whether they are horizontal or tilted, have openness values of 90°
Normalised height	Derived from bathymetry. Normalised height considers the extension of a catchment area of a specific terrain point. Normalised height allots a value of one to the highest and value zero to the lowest position within a respective reference area.
Slope height	Derived from bathymetry. It is defined as the vertical distance from the base of the slope to the crest of the slope (i.e. the line of intersection of the two slope planes). If the crest of the slope is not horizontal, the Slope Height is measured from the point of intersection of Joint plane one with the crest.
Terrain Ruggedness Index (TRI)	Derived from bathymetry; it expresses the difference between minimum and maximum cell value and its eight neighbours.
Valley Depth	Derived from bathymetry, it is calculated as a vertical distance to a channel network base level (drainage patterns across a DEM (i.e. the direction water would flow across terrain when above sea level)). The network base level is subtracted from the original elevations in the DEM.

†Negative openness was derived from a rescaled 10 m bathymetry raster to improve the computational speed

A semi-automated approach (OBIA) was utilised to segment and classify the acoustic data based on the morphology and substrate type. The preliminary stage of the OBIA mapping approach consists in the creation of MBES derivatives (slope, BPI, roughness, etc.) from the original layers.

ESRI ArcMap and the geoprocessing tools of System for Automated Geoscientific Analyses (SAGA) for QGIS were used at this stage. A selection of layers that best captured the differences at seabed were then loaded into the workspace of eCognition. The weighting of these layers, as used by the multi-resolution segmentation algorithm, is determined based on how these layers were understood to best describe the geomorphology of the study area.

The multi-resolution segmentation algorithm used in this study partitions an image into regions (called objects) with homogenous attributes, across a user-defined set of layers and level of allowed variability (scale parameter) as well as effect of object shape (compactness and shape parameters). In this study, segmentation was carried out in a hierarchical manner, starting with larger objects and breaking them into smaller units with each step, to find the best possible representation of real seabed features. The hierarchical approach creates super- and sub-objects related to each object level, which can also be utilised to describe each object.

A first segmentation step was made using a scale parameter (SP) of five. The compactness (C) and shape (S) parameters were kept at 0.5 and 0, respectively. The first segmentation was used to classify the seafloor into Ridges and Planes. Two further segmentations were then run within segments of each of these classes. In these segmentations SP, C and S were kept the same as in the first segmentation for all but the last segmentation in the Plane class, where SP was set at two. The weightings used for the environmental layers in each level of segmentation are shown in Table 24 and the process flow is schematised in Figure 32.The objects created (a total of 71,747) accurately represented real features at seabed and the classification was carried out at this level. Two morphological classes (ridges and planes) and three sedimentological subclasses (rock, coarse sediment and fine sediment) were considered appropriate for mapping.

Table 24. Segmentation parameters used in geomorphic zonation.

Layer	Weighting				
	General Segment	Ridge Segment 1	Ridge Segment 2	Plane Segment 1	Plane Segment 2
Backscatter*	0	0	0.2	0	0
BPI 5	1	0	0.8	1	1
BPI 10	0.5	0.5	0	0	0.5
BPI 25	0.2	2	0	1	0
Negative openness†	0.1	0.5	0	0.1	0.1
Std. Dev. (Bathymetry)	1	0	0	0.8	0.5
Terrain Ruggedness Index (TRI)	0.2	0	1	1	1

* Backscatter for the 2017 datasets was reduced to 2 m resolution to improve the computational speed and reduce crashes. †Negative openness was derived from a rescaled 10 m bathymetry raster to improve the computational speed.

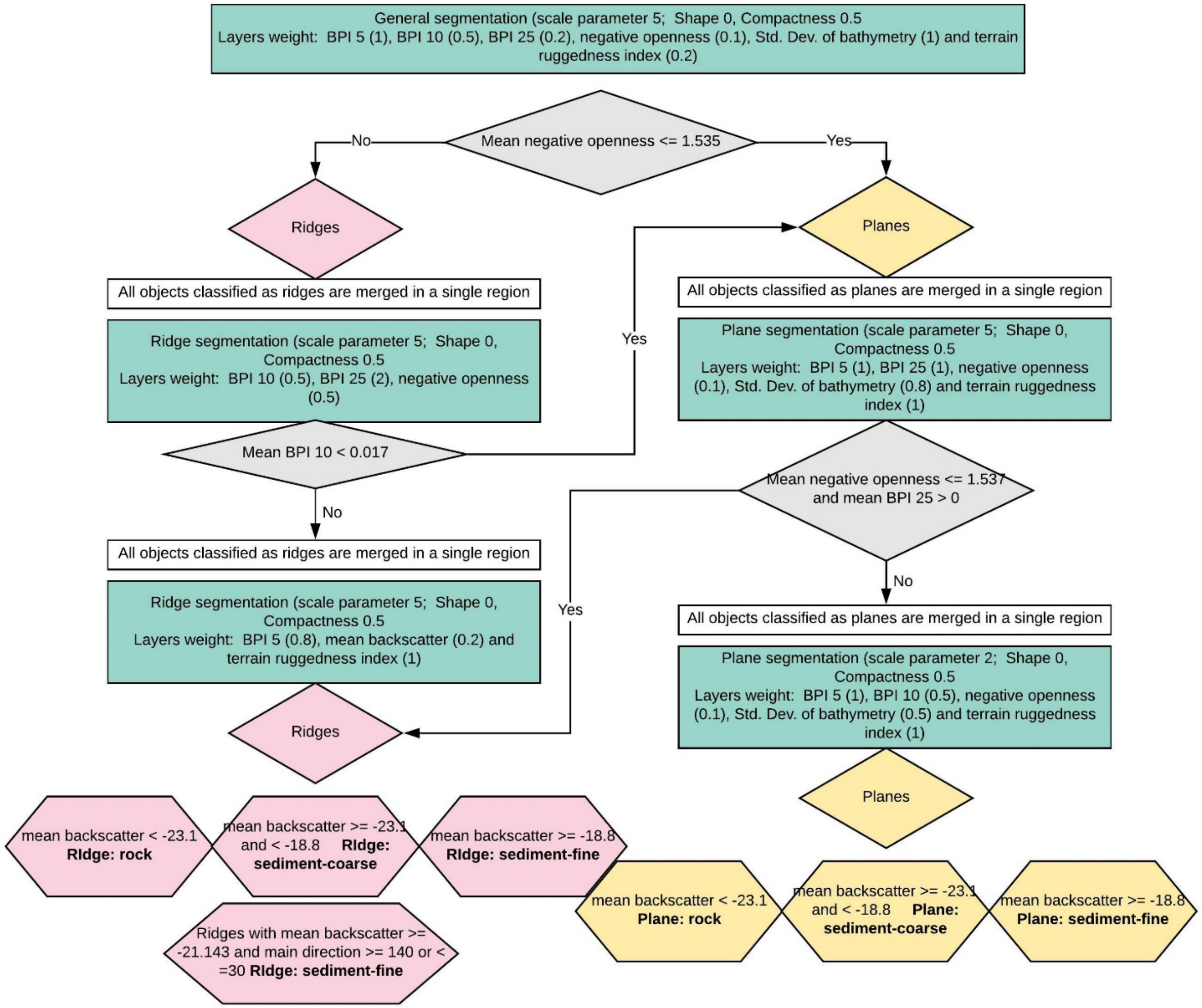

Figure 32. Flow chart schematising the segmentation and classification process adopted with eCognition. The class “boulders to pebbles” is indicated as “sediment-coarse” and the class “gravel to sand” as “sediment-fine”.

A selection of layer attributes, including summary and textural statistics, were calculated for the objects. These included: object mean and standard deviation for all the layers used and some geometric properties (i.e. the Main Direction, Asymmetry and Roundness). Groups of 100 objects for each separate class were selected from the segmented data visually, by expert judgement, to act as samples for the habitats. Selection of rock vs sediment flat was guided by, and included, locations of groundtruthing data (video and stills) with > 50 % abundance of bedrock leading to classification as “rock platform”. Sediment ridges did not have groundtruthing stations on them, but they are readily identifiable using expert judgement based on morphology, alignment and migration patterns.

The objects, with their accompanying attributes, were exported from eCognition as a polygon shapefile for further analysis. The data were imported into R (version 3.4.1: R Core Team 2017). Variables that best separated habitat classes were selected, using the boruta algorithm in the ‘Boruta’ package in R (Kursa & Rudnicki 2010) and excluding correlated variables. The algorithm consists of an iterative permutation procedure, which compares the importance of a variable in a Random Forest model (Liaw & Wiener 2002) to the importance of a random permutation of the same variable over several iterations. Variable importance is determined by the effect that removal of each variable in turn has on the mean internal model accuracy. Only predictor variables with mean importance scores significantly higher than the mean of the permuted variables are selected.

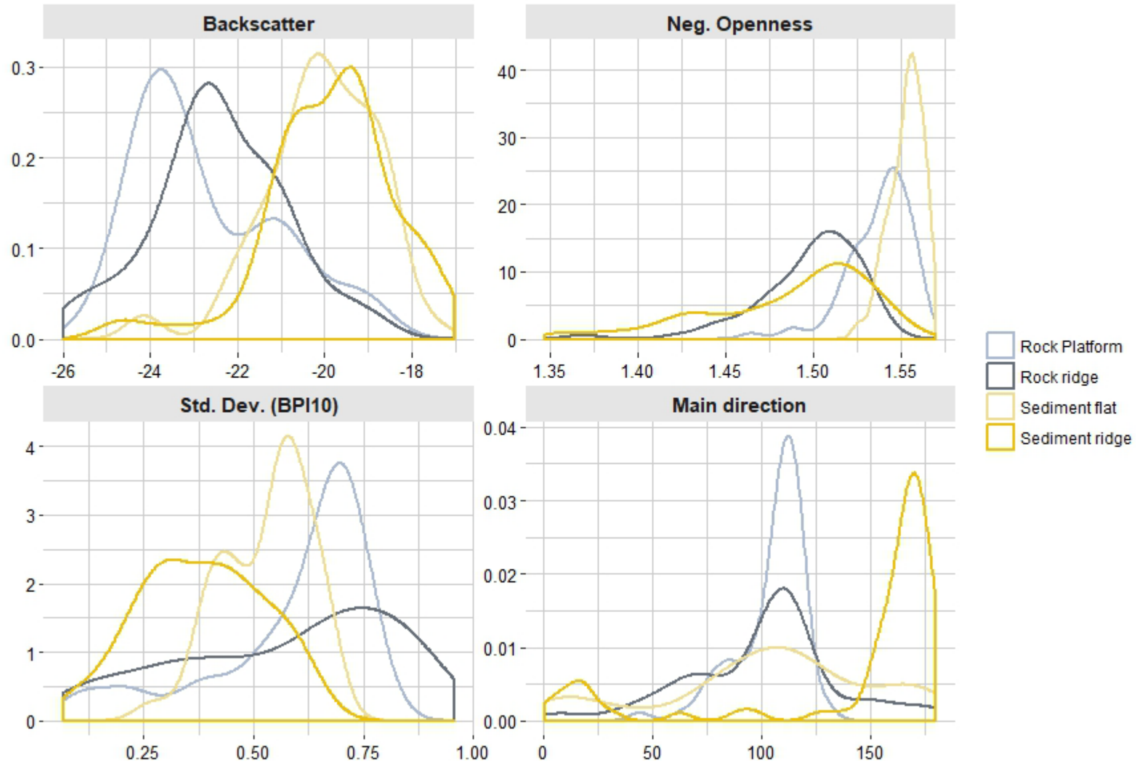

Figure 33. Density of observed values in samples of each assigned habitat for the four object attribute variables that best separate the classes.

Variables were further reduced by inspecting correlations among predictors. Out of a set of correlated (|r| > 0.5) variables, those to be retained were selected based on the importance score combined with a visual inspection of boxplots of the predictors against classes.

The four most effective object attributes for separating habitat classes were: (1) mean backscatter, (2) mean negative openness, (3) Std. Dev. BPI 10, (4) mean direction (Figure 33). Threshold values of class separation obtained from this exercise where then adjusted on eCognition in order to perfect the classification and extend it to the totality of the object.

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