NMBAQC

NE Atlantic Marine Biological Analytical Quality Control Scheme

JNCC

Joint Nature Conservation Committee

Epibiota Remote Monitoring from Digital Imagery: Interpretation Guidelines

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Summary

There is increasing recognition that the effective acquisition and interpretation of underwater video and still image data for biodiversity is growing in importance. Numerous organisations (e.g. Statutory Nature Conservation Bodies (SNCBs), Inshore Fisheries Conservation Authorities (IFCAs), environmental consultancy agencies, industry and academic institutes) are now engaged in this work for a variety of different purposes, including:

- Marine habitat mapping of physical seabed habitats and features in support of a variety of national and international initiatives, e.g. Integrated Mapping For the Sustainable Development of Ireland's Marine Resource (INFOMAR).
- Characterisation of the epibiotic attributes of seabed habitats and features e.g. in support of the Marine Strategy Framework Directive, Water Framework Directive, designation of Marine Protected Areas (MPAs, European and National), marine development applications and licensing.
- Monitoring trends in seabed habitat features and their associated epibiotic communities, e.g. in support of monitoring the effectiveness of management measures implemented to achieve given conservation objectives within MPAs and also to assess and monitor predicted impacts for given marine developments and the effectiveness of mitigation measures implemented.

The guidelines in this document provide a summary of current best practice for the interpretation of video and stills imaging data of benthic substrata and epibenthic species to ensure that data are interpreted to fulfil the objectives of a survey.

These guidelines form part of the epibiota component of the NMBAQC scheme, reporting to the Healthy and Biologically Diverse Seas Evidence Group (HBDSEG) under the UK's Marine Monitoring and Assessment Strategy (UKMMAS).

Table of Contents

Abbreviations

AFBINI	Agri-Food and Biosciences Institute
ArcGIS	Arc Geographic Information System (a visualisation tool)
AUV	Automated Underwater Vehicle
BGS	British Geological Survey
BS	British Standard
CCW	Countryside Council for Wales (now: Natural Resources Wales)
CD	Compact Disc
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CPCE	Coral Point Count with Excel extensions
CRP	Central Reference Point
DASSH	Archive for Marine Species and Habitats Data
DV	Digital Video
DVD	Digital Versatile Disc
EN	European Norm
EU	European Union
EUNIS	European Nature Information System
FOCI	Features of Conservation Importance
FOV	Field of View
HBDSEG	Healthy and Biologically Diverse Seas Evidence Group
ICES	International Council for the Exploration of the Sea
IFCA	Inshore Fisheries Conservation Authorities
INFOMAR	Integrated Mapping For the Sustainable Development of Ireland’s Marine Resource
IROS	Intelligent Robots and Systems
ISBN	International Standard Book Number
ISO	International Organisation for Standardisation
JNCC	Joint Nature Conservation Committee
LAPM	Large Area Photo Mosaicing
MARLIN	MARine Life Information Network
MCZ	Marine Conservation Zone
MEDIN	Marine Environmental Data and Information Network
MESH	Mapping European Seabed Habitats
MMR	Marine Monitoring Report
MNCR	Marine Nature Conservation Review
MPA	Marine Protected Area
MSBIAS	Marine Species of the British Isles and Adjacent Seas
MSS	Marine Scotland Science
NBN	National Biodiversity Network
NMBAQC	Northeast Atlantic Marine Biological Analytical Quality Control Scheme
NRW	Natural Resources Wales
OBIA	Object Based Image Analysis
OSPAR	Oslo/Paris convention (for the Protection of the Marine Environment of the North-East Atlantic)
OTU	Operational Taxonomic Unit
PMFs	Priority Marine Features
px	pixels
QA	Quality Assurance
RAW	unprocessed or raw data
RGB	Red, Green, Blue
ROG	Recommended Operating Guidelines
ROV	Remotely Operated Vehicle

SAC	Special Area of Conservation
SACFOR	Superabundant, Abundant, Common, Frequent, Occasional, Rare
SCI	Site of Community Importance
SCUBA	Self-Contained Underwater Breathing Apparatus
SNCB	Statutory Nature Conservation Body
SNH	Scottish Natural Heritage
SOP	Standard Operating Procedures
TIFF	Tagged Image File Format
UK BAP	United Kingdom Biodiversity Action Plan
UKMMAS	UK Marine Monitoring and Assessment Strategy
USBL	Ultra-Short Base Line
UV	Ultraviolet
VENUS	Victoria Experimental Network Under the Sea
VFC	Visual Fast Count
WKNEPHBID	WorKshop and training course on NEPHrops Burrow IDentification
WORMS	World Register of Marine Species
WW	West Wales

1 Introduction

This report provides best practice guidance for the interpretation of videographic and photographic imagery to extract epibiotic data. This document complements the joint guidance prepared by the Northeast Atlantic Marine Biological Analytical Quality Control Scheme (NMBAQC) and Joint Nature Conservation Committee (JNCC) for best practice in the operational aspects of remote video monitoring (Hitchin *et al* 2015). This shall be referred to as the “Operational Guidelines” henceforth.

Video and still image cameras are extremely valuable and flexible tools for providing evidence for benthic monitoring and mapping. Video footage can be used to achieve numerous objectives. For example, investigating previously unsurveyed areas of seabed; characterising habitat types and locating boundaries by providing information on the condition of the substratum and the distribution and abundance of epibiota; 'ground-truthing' remotely-sensed information; and detection of additional seabed features of interest, such as trawl scars.

As the methods are typically non-destructive, they are considered appropriate for sampling protected, fragile or sensitive areas. Still images provide a high quality visual record that can enable a greater level of identification of epibiotic taxa and offer the increased ability to undertake quantitative analyses of imagery derived data. Depending on their specific purpose, surveys can be designed to collect descriptive, semi-quantitative or quantitative information from the benthos.

Video and still image quality can be affected by a number of environmental and operational factors, including swell, turbidity, lighting, tidal flow, height above the seabed and towing speed. As quality reduces so does the size of organisms that can be accurately identified and counted with confidence and the level of taxonomic resolution that can be achieved. Image quality is therefore directly linked to the confidence in the results obtained.

The Operational Guidelines provide information on obtaining the best quality imagery. This guidance, the Interpretation Guidelines, provide complementary information on how to best analyse the imagery to obtain the highest quality information possible from it. Unlike the Operational Guidelines, the Interpretation Guidelines are not platform specific.

1.1 Previous guidance

This guidance aims to build upon standards and protocols for video and still image interpretation and analysis in the UK. Current standards and advice are provided by:

- BS EN 16260:2012. *Water quality - Visual seabed surveys using remotely operated and towed observation gear for collection of environmental data*;
- Procedural Guideline No. 3-12: *Quantitative surveillance of sublittoral rock biotopes and species using photographs* (Bullimore and Hiscock, 2001);
- Procedural Guideline No. 3-13: *In situ surveys of sublittoral epibiota using hand-held video* (Munro, 2001);
- Procedural Guideline No. 3-5: *Identifying biotopes using video recordings* (Holt and Sanderson, 2001).

This guidance focuses on specific and practical approaches to the analysis of remote video and still images. A number of useful documents and websites are listed throughout this document in the relevant sections. The guidance, however, does not focus on the operational aspects of data collection, especially sampling, as this is covered in greater detail within the Operational Guidance (Hitchin *et al* 2015) and the Mapping European Seabed Habitats (MESH) Recommended Operating Guidelines (ROG) for underwater video and photographic imaging techniques (Coggan *et al* 2007).

1.2 Terminology

The guidance in this report is split into two levels:

1. If a recommendation includes the term "**must**" then this is mandatory for organisations completing analysis of digital imagery to contribute to statutory UK monitoring programmes.
2. If a recommendation includes the term "**should**" then this is mandatory where practicable for these organisations.

2 Video analysis

For all surveys, analysts **must** be given a clear understanding of the objectives and expected subsequent use of the datasets, allowing the analysts to work at the correct taxonomic levels and allowing the production of a dataset suitable for its intended purpose.

Video analysis packages **must** allow frame capture, fast forward / rewind control, frame by frame progression and loop replay.

Common screen set-ups vary and technology is constantly advancing. High quality monitors with a resolution capable of displaying HD (1080i) video and still images at a resolution >90 dpi **should** be used. The monitor **should** also be capable of contrast, brightness and colour adjustment, and be backlit if possible. Where practical a minimum of two screens **should** be used in extended desktop mode. This allows for easy viewing of data sheets and/or still images alongside the video.

2.1 High level review

Video footage **must** be watched from start to finish multiple times. This will depend on the aims of the survey and the habitat in questions. The first viewing **should** be used as an initial scan of the footage and then further viewings for more detailed analysis. Videos of multiple and more complex habitats (e.g. rocky reef) may require more viewings than those of a single or simpler habitat types (e.g. sand).

The initial scan of the footage is required in order to do the following (this review **must** be undertaken at a speed that does not exceed four times the normal viewing speed):

1. Assess whether the video is of adequate quality to be analysed for the purpose of the study.

a. It is recommended in the Operational Guidelines that an initial assessment of quality is provided with the video footage in the accompanying logsheet (Hitchin *et al* 2015). The analyst **must** also provide a rating of the quality.

b. A number of criteria can be used to determine video quality including:

   i. Camera distance to seabed

   ii. Angle of the field of view of the camera

   iii. Speed of camera over ground

   iv. Level of turbidity

   v. Lighting quality

   vi. Presence or absence of scale (while not affecting the quality this does affect the ability of the analyst to correctly analyse the video)

c. Example categories can include (It must be noted that not all criteria have to occur for the video to be placed in a certain category), summarised in Table 1:

   i. ***Excellent*** - Water is clear, perfect illumination, colour is excellent, camera moving at ideal speed and at a constant angle (or as close to when using drop frames), sea bed is visible at all times. There may be very occasional issues with viewing the seabed but these occurrences last for <5 % of the tow. All levels of analysis are expected to be possible;

   ii. ***Good*** - Seabed easily observed, small amounts of suspended matter but this does not affect the visibility, speed may occasionally vary, lighting is sufficient to appropriately illuminate organisms. There may be occasional issues with viewing the seabed but these occurrences last for 5-20 % of the tow. This level of quality is not expected to affect analysis, level 5 biotope analysis is likely to be possible;

   iii. ***Poor*** - Suspended matter, dense fauna or flora (e.g. kelp) or disturbed sediment results in a partially obscured view of the seabed. Camera speed and distance to the seabed is variable throughout the tow. Constant stop-start, particularly in the case of sledge systems on sediments, can often result in reduced visibility. There is general uncertainty as to whether all target objects can be recorded. These problems are present for 20-50 % of the tow. High level taxonomic identification will be difficult from this point. Quantification of organisms may still be possible but it is recommended that a qualitative assessment of abundance is used. Broadscale habitat mapping (EUNIS Level 3) is still possible;

   iv. ***Very Poor*** - Suspended matter, dense fauna or flora (e.g. kelp) or disturbed sediment obscures most of the seabed. When the seabed is visible the camera is often moving too fast, resulting in constant blurring of organisms. Camera often moves too far from the seabed resulting in a lack of illumination and visibility. These problems are likely to be present for 50-80 % of the tow. Quantitative or qualitative estimates of organism abundance are not recommended. It may still be possible to determine broadscale habitats;

v. ***Zero*** - For whatever reason (camera too far from the seabed, camera moving too quickly, lack of illumination, sediment disturbance, dense gathering of fauna or flora (e.g. kelp)), there is no view of the seabed at all for >80% of the tow. Data are not usable.

Table 1 Summary of video quality criteria

Quality Category	Proportion of tow negatively affected	Organism Enumeration	Biotopes
Excellent	<5 %	Quantitative	Level 5
Good	5-20 %	Quantitative	Level 5
Poor	20-50 %	Qualitative	Level 3
Very Poor	50-80 %	Not recommended	Level 2/3
Zero	>80 %	Data not usable	Data not usable

d. If the quality is deemed very poor or zero, then it is recommended that the video **should** not be analysed further (Ideally when the image quality is this low, the tow should be terminated as recommended in the Operational Guidelines (Hitchin *et al* 2015)). In cases where it is necessary for very poor data to be analysed, then caveats **must** be placed on the data.

e. In some cases the quality of footage may significantly deteriorate / improve during a video tow. In this case it may be appropriate to segment the video into differing quality categories.

2. Obtain an overview of the habitats and species found. It may also be useful to assign a measure of habitat rugosity (see Annex 1: Rugosity) if appropriate to the survey.

3. Segment the video:

   a. Depending on the aim of the survey, segment the video either at a coarse level, for example representing broadscale habitat / substratum changes (equivalent to EUNIS level 3, Annex 2) or into equal sections (e.g. for Visual Fast Count method see Section 2.3.2), see for example figure 1. Brief changes (lasting less than a 5 m x 5 m area, the minimum biotope area defined by MNCR) in substrata should be considered as incidental patches and so may not be logged as separate sections but **should** still be recorded as part of the habitat description. The time taken to cover an area of this size will be dependent on towing speed. All video time **must** be linked to positional data so that, when this is combined with the field of view of the camera, the area covered can be calculated.

   b. For each segment identified during this review the following **must** be noted from the information on the video overlay or accompanying metadata (this information should be recorded in the video logsheet as recommended in the Operational Guidelines (Hitchin *et al* 2015)):

      i. Start and end time;

      ii. Start and end position;

iii. Depth at the start and the end of the tow. However, if there are large variations in depth throughout the tow then the range, including minimum and maximum depths, **must** be noted.

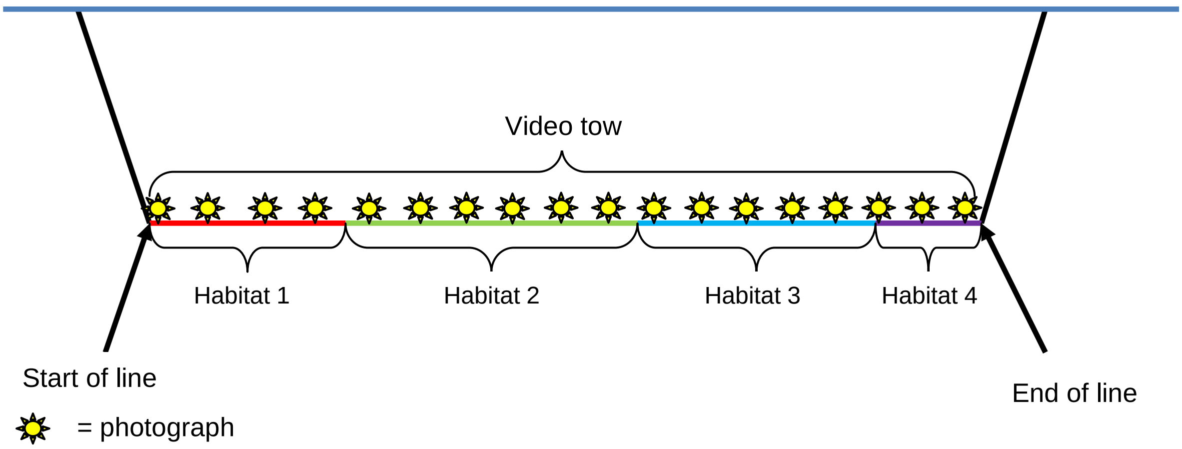

Figure 1 Simplified illustration of method for segmenting seabed video tows based on changes in habitat. Marine Recorder Briefing Note, JNCC.

2.2 Further analysis of video

To carry out more detailed analysis each video segment (of sufficient quality) **must** be viewed at actual or slower than actual speed. If available, still images from the respective video tow **should** be viewed alongside the video to assist with interpretation due to their higher resolution.

The area of each transect **should** be estimated (particularly for camera sledge or flying array systems). The field of view of the camera can be determined using the scaling device. Transect length can be calculated from the positional data.

Further ways to calculate field of view, and thus area surveyed, can be found in Section 3.1.2.

It is also possible to account for changes in height of the camera above the substratum where organisms are only enumerated if they pass through a certain area of the video footage, e.g. between two laser points that remain a fixed distance apart (see Sheehan *et al* (2010) for an example). Density of organisms can then be calculated.

2.2.1 Taxon identification

It is a usual requirement that all species, or a select group of indicator species, be identified from a video. The level of species identification will often depend on the aims of the survey but the analyst **must** be certain about the level of taxonomic classification that is assigned. If the analyst is not certain at identifying individuals from a particular survey at a certain taxonomic level then they **must** move to a higher taxonomic level, e.g. from species to genus to family etc.

A note can then be added to the data entry sheet stating what the analyst suspects the finer level identification of the organism to be. This may be subsequently reviewed by a more experienced taxonomist if more detail is required.

Nomenclature **must** conform to established inventories. The analyst is directed to the World Register of Marine Species (WoRMS) website[1]. If a detailed taxonomic identification is not possible a description can be given, e.g. “yellow encrusting sponge”, alongside the taxonomic level selected i.e. “Porifera” or “Animalia”.

It is recommended that the spatial co-ordinates where uncertain taxonomic identifications are made **should** be recorded. This **should** also be applied to organisms that are of particular interest to a survey, such as Marine Conservation Zone Features[2] (Annex 3), Priority Marine Features (PMFs)[3] and Non-native species[4].

For certain taxa, especially those from the phylum Porifera, it is not possible to identify to the organism to species level from digital imagery alone (Goodwin and Picton, 2011). Further details on difficult taxa including alternative ways of recording, such as the use of morphotypes, can be found in Section 4.

It is recommended that a reference library of taxonomic images **should** be kept for a variety of reasons (see further detail in Section 4.2). This can include good examples of organisms to assist with identification in the future, as well as images where species level identification is not certain. These may be useful for quality assurance purposes in the future where an expert may be able to provide certain identification. It is also recommended that ID guides are consulted throughout the identification of organisms (such as the Encyclopaedia of Marine Life of Britain and Ireland[5]). The MarLIN deep-sea image catalogue[6] is a highly useful resource for the identification of deep-sea species. Additionally, there are further taxonomic references listed on the NMBAQC website[7].

2.2.2 Determining abundance of organisms

It is recommended that quantitative data are extracted from imagery wherever possible. This enables analyses of abundance, diversity and population structure to be undertaken with some degree of statistical significance. However, it is acknowledged that for some surveys semi-quantitative or qualitative data may be considered acceptable, especially if the video is of lower quality.

There are several ways that an organism’s occurrence in the collected imagery may be recorded, either quantitatively or qualitatively. The options that the analyst has may depend on the project scope, equipment set-up, analyst time and also the quality of the footage. The choice to use one or more particular data extraction measure should be carefully made as this will affect the representation of the community under investigation. For example, van Rein *et al* (2012) showed that three different extraction measures (point counts, visual estimation and frequency of occurrence) created statistically different representations of the exact same community. The general options for recording the occurrence of organisms are outlined below, in order of increasing information:

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[1] http://www.marinespecies.org/
[2] Details of these features can be found here
[3] Details of the features can be found here
[4] Details here
[5] http://www.habitas.org.uk/marinelife/
[6] http://www.marlin.ac.uk/deep-sea-species-image-catalogue/
[7] http://www.nmbaqcs.org/scheme-components/epibiota/taxonomic-references/

Presence / Absence – Note whether a taxon is present along a particular tow. This option is the quickest method to extract data from imagery, however, it limits the possibilities for statistical analysis. For example, the power to detect change in community structure is greatly reduced as no information is recorded about the relative abundance of each taxon. The relative importance of each species is also difficult to estimate without proportional representation of taxa. However, presence / absence data can easily be compared over years and between sites. Errors in the dataset are also likely to be few in number when compared to other methods of analysis, although there will still be issues with regards to cryptic and hard to identify taxa.

SACFOR[8] - A scale that can be used to produce semi-quantitative estimates of abundance. The scale was initially developed as a method to obtain a broad overview of the environment. This provides a useful guide for qualitative and semi-quantitative studies and can give an idea of the composition of species assemblages and the relative abundance of species within an assemblage. With experience, the scale can be used to make useful broad comparisons between different sites. This method of enumeration, however, is not suitable for looking to detect finer scale trends in benthic communities (counts and percentage cover will be preferred). The SACFOR scale is often used as a rapid process of determining biotopes. Details can be found on the JNCC website (Annex 4).

It should be noted that there can be inconsistencies with this metric. Different observers may assign organisms to different size categories, e.g. hermit crabs of the genus *Pagurus* may be assigned to the 1 – 3 cm or 3 - 15 cm categories, which may influence results. It is recommended that when assigning organisms to size classes that it is based on the maximum size of the organism to improve consistency. The Marine Life Information Network (MarLIN) can be a useful resource, providing length ranges for many common marine species[9].

Counts – Actual numbers of organisms allow for the greatest variety of statistical analyses to be conducted on the data. For quantitative analyses countable organisms **must** be counted by viewing the video and consistently recording each identifiable organism according to the analysis schedule being used. The raw count can be converted into density (individuals m^{-2}) by dividing the count by the calculated area sampled, using the length of the video tow and the field of view of the camera (N / (tow l x FOV)). It should be noted that colonial and encrusting organisms are often recorded as percentage (%) cover; this is detailed further in Section 4.1.

Percentage cover - Some organisms (e.g. sponges) have individuals that vary enormously in size whereas for others (e.g. colonial ascidians or zoanthids) the extent of a single individual is not obvious. In these situations, abundance should be recorded using percentage cover. The most common methods are:

- **Visual estimation**, where a quadrat is overlain on a video frame or still image and the percentage cover recorded. This is the simplest procedure to undertake but is inherently the least accurate. Figure 2 provides assistance with estimating percentage cover.

[8] SACFOR stands for Super-abundant, Abundant, Common, Frequent, Occasional or Rare. The JNCC website provides guidance on how to use this scale for recording abundance of various marine species.
[9] http://www.marlin.ac.uk/

- **Point counts**, where a quadrat with a predetermined number of points (usually 50 or 100), is overlain on a video frame grab or still image. Points can be either randomly or evenly spaced, and the percentage of those points which contain the organism in question is recorded. When the position of points are recorded on the video frame grab or still image, the identification made under that point can be later verified by another analyst. This builds additional Quality Assurance (QA) to the method and can increase the confidence in extracted data. Points could also be stratified if two or more clear habitats were in all quadrats. Point counts can be sensitive to change if a statistically valid number of points are analysed, but can result in the failure to record rare organisms, thus underestimating species richness (van Rein *et al* 2011a, 2012).

- **Frequency of occurrence**, where a quadrat with a predetermined grid is overlain on a video frame grab or still image. The grid divides the quadrat into equal proportions, from which the presence of taxa within are recorded as either present or absent. The more squares in the grid the higher the resolution of the resultant data. For example, a 5 x 5 grid will overlay the quadrat with 25 squares. Every occurrence of a taxon within a square will score it 4 % coverage. If the taxon occurs in every square then it occurs in 100% of the image. For a higher resolution grid made of 100 squares (10 x 10), each occurrence of a taxon will score it 1 % coverage. Although this method removes potential errors between estimates made by different observers, it tends to make data that over-represent the true occurrence of a taxon (van Rein *et al* 2012).

It can be common practice to enumerate organisms using percentage cover from entire video sections/tows, particularly using visual estimation. However there can be large errors associated with this as values can be affected by the subjectivity of different observers. If this method is used it is highly recommended that the video is split into equal sections and percentage cover of the organism is estimated for each section individually, then averaged. Using a grid overlay while analysing the video can help to improve accuracy and precision of values.

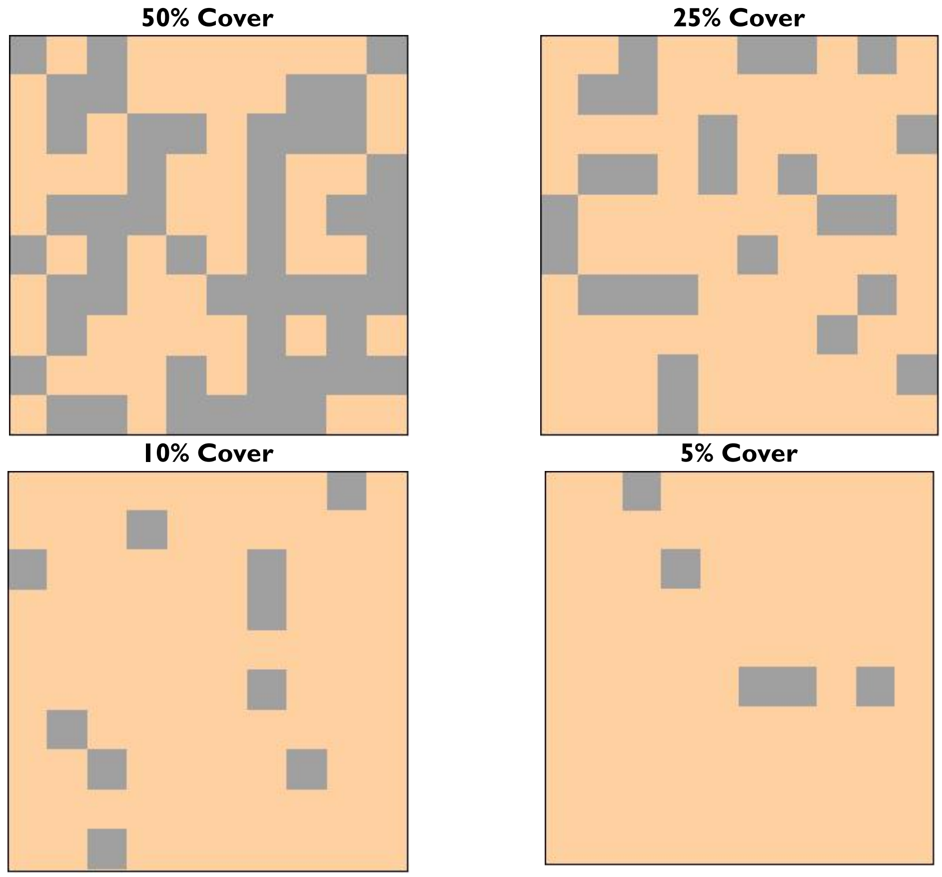


Figure 2 Graphical illustrations to assist with estimation of percentage cover (from Envision 2010, video ring test analysis tools).

2.2.3 Sediment classification

While grabs and cores remain the optimal methods to ground truth sedimentary areas, some details on these habitat types can be gleaned from digital imagery for mapping purposes. Surface sediment type may be determined using the adapted Folk sediment triagon (Figure 3) and the Wentworth scale (Table 2 and Figure 4 and 5). It is recommended that video is not used to distinguish between muddy sands and sandy muds as they can appear very similar. Physical samplers are more appropriate for finer levels of detail.

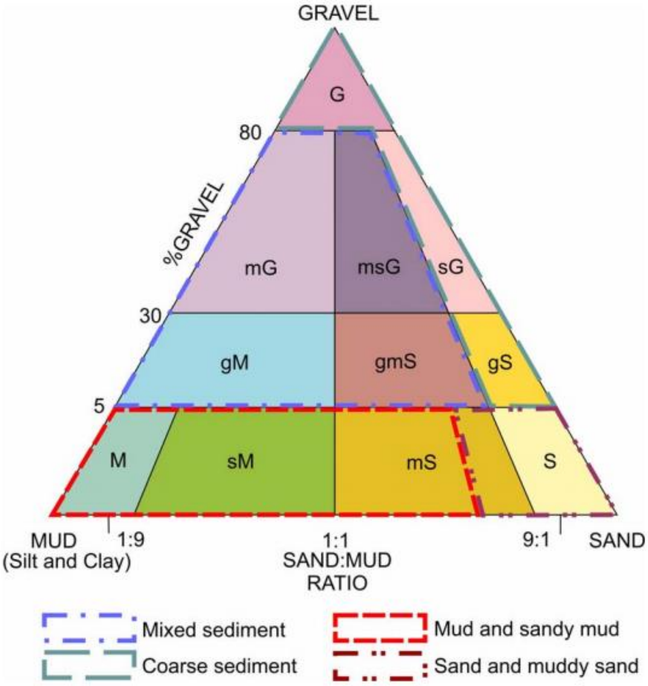


Figure 3 Modified Folk triagon (Long 2006).

Table 2 Wentworth scale and particle sizes

ϕ scale	Size range	Size range	Aggregate name	Other names
	(metric)	(approx. inches)	(Wentworth Class)	
< −8	> 256 mm	> 10.1 in	Boulder	
−6 to −8	64–256 mm	2.5–10.1 in	Cobble	
−5 to −6	32–64 mm	1.26–2.5 in	Very coarse gravel	Pebble
−4 to −5	16–32 mm	0.63–1.26 in	Coarse gravel	Pebble
−3 to −4	8–16 mm	0.31–0.63 in	Medium gravel	Pebble
−2 to −3	4–8 mm	0.157–0.31 in	Fine gravel	Pebble
−1 to −2	2–4 mm	0.079–0.157 in	Very fine gravel	Granule
0 to −1	1–2 mm	0.039–0.079 in	Very coarse sand	
1 to 0	0.5–1 mm	0.020–0.039 in	Coarse sand	
2 to 1	0.25–0.5 mm	0.010–0.020 in	Medium sand	
3 to 2	125–250 µm	0.0049–0.010 in	Fine sand	
4 to 3	62.5–125 µm	0.0025–0.0049 in	Very fine sand	
8 to 4	3.90625–62.5 µm	0.00015–0.0025 in	Silt	Mud
> 8	< 3.90625 µm	< 0.00015 in	Clay	Mud
>10	< 1 µm	< 0.000039 in	Colloid	Mud

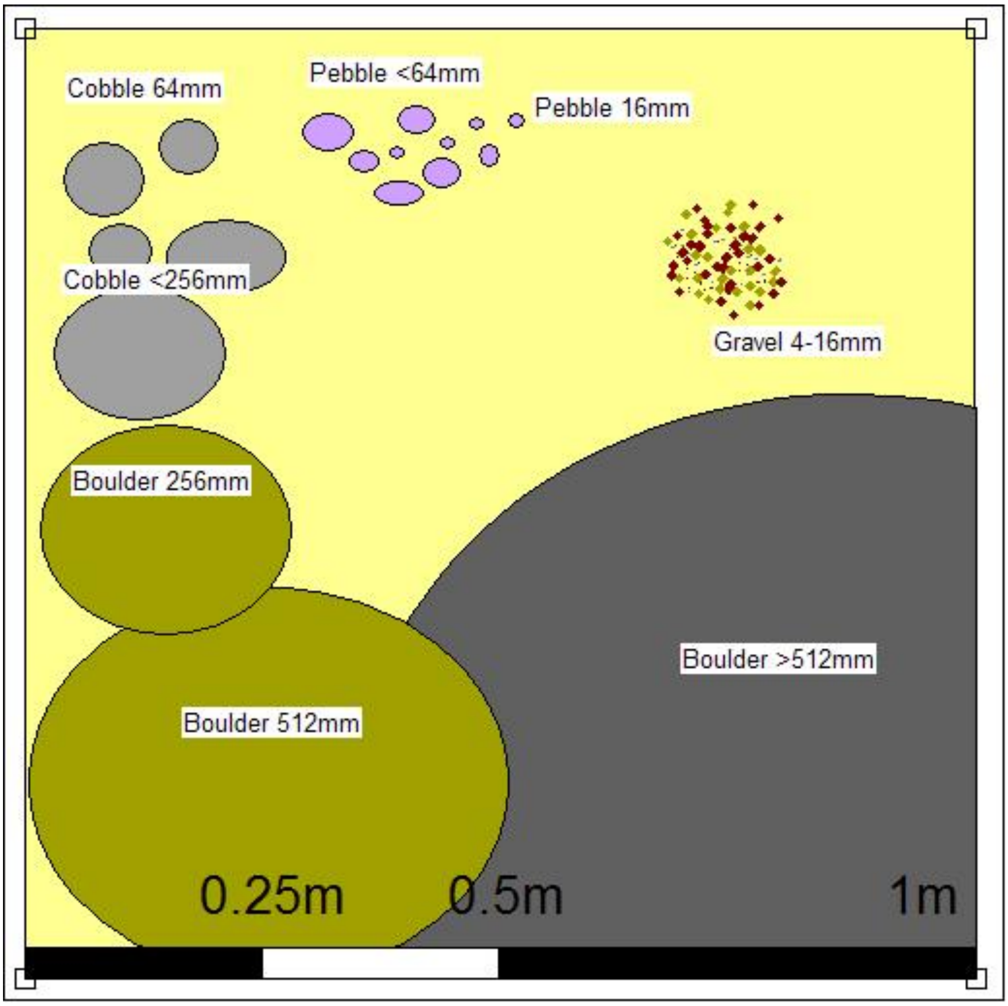


Figure 4 Graphical representation of various sediment sizes within a 1 m field of view (Envision Mapping Ltd 2010).

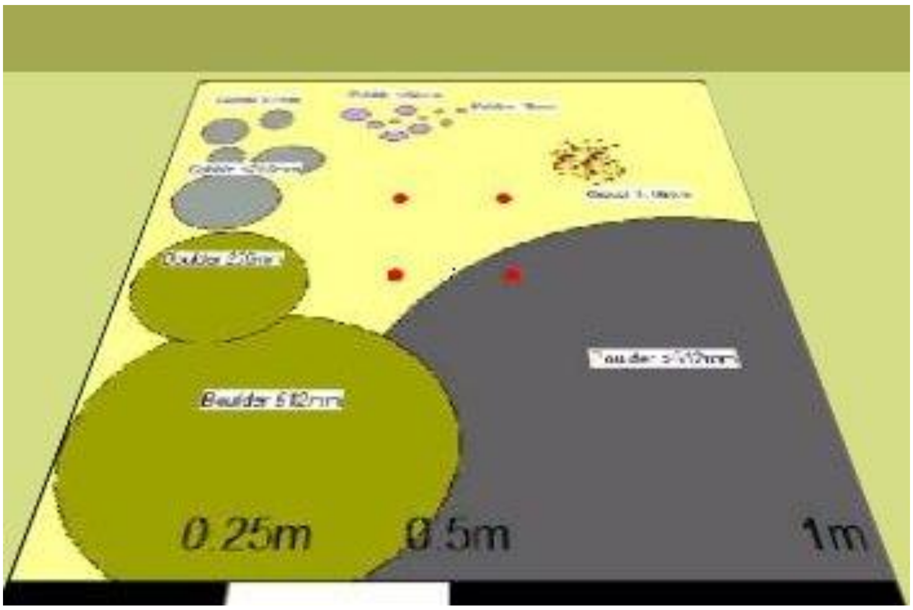


Figure 5 Graphical representation of various sediment sizes within a 1 m field of view in perspective (Envision Mapping Ltd 2010).

2.2.4 Biotope interpretation

For biotope-level interpretation, incidental patches would be considered to be areas smaller than 5 m x 5 m (the accepted guidance is that a biotope may not be smaller than 5 m x 5 m (Connor *et al*., 2004)). This should be noted for mapping purposes.

Where biotope assignments are to be made, each segment **must** be analysed and the segment assigned to the appropriate level of the JNCC Marine Habitat Classification for Britain and Ireland[10] and/or European Nature Information System (EUNIS)[11] hierarchy. This level **must** not exceed that suggested for analysis based on the quality of the video (Section 2.1), i.e. Level 3 is the highest level poor quality video can be assigned to. For sediment habitats with sparse epifauna, it may not be possible to assign a biotope at level 5 based on the biological community.

More detailed information from the still images taken within the video segment can be used to help assign a biotope. Detailed guidance of biotope identification can be found in JNCC reports 529 and 546 (Parry 2014; 2015). Guidance by Parry (2015)[12] **should** be followed when assigning biotopes to survey data.

In some areas habitat can be particularly patchy and it is not uncommon for an entire video tow to be comprised of continuously small patches of habitat less than 5 m x 5 m. This makes it difficult to allocate one biotope for the whole tow or to divide the tow into numerous habitats of alternating biotopes (see Section 2.1). In this case it is appropriate to call this habitat a biotope mosaic of the repeating biotopes. This can be common in areas where the sediment may occur as a thin veneer over a rocky habitat.

2.3 Specialist techniques

There are some additional techniques that have been designed for specific situations.

2.3.1 Counting burrows

Protocols for *Nephrops* burrow counting for all UK *Nephrops* grounds have previously been developed. The reader is directed to the ICES *Nephrops* burrow identification workshop report for further guidance (ICES 2008)[13]. This paper documents the workshop on *Nephrops* burrow identification with the aim of agreeing upon a common protocol for counting burrows to improve consistency. The document highlights guidance for burrow identification, including the following:

> “1) At least one burrow opening is usually distinctly crescentic (crescent, half moon) in shape. Where the angle of view permits sight of the tunnel beyond this opening, the angle of descent is usually shallow.
>
> 2) There is often evidence of expelled sediment, usually in a broad delta-like ‘fan’ at the burrow opening, and scrapes and tracks made by the chelipeds and pereiopods are often apparent. These features and a clean, un-collapsed burrow opening suggests current occupancy (collapsed or partially collapsed burrows are unlikely to be occupied and should be ignored). However, beware if there has been recent passage of a trawl – displaced sediment may have spilled into occupied burrows and may yet to be cleared

[10] http://jncc.defra.gov.uk/marine/biotopes/hierarchy.aspx
[11] http://eunis.eea.europa.eu/habitats-code-browser.jsp
[12] Guidance available at http://jncc.defra.gov.uk/pdf/Report_546_web.pdf
[13] ICES 2008 Paper

by the occupant. An occupied burrow may have both collapsed and functional openings.

3) Secondary openings may be similarly crescentic but are often more circular and with a steeper connecting tunnel/shaft.

4) Look for clusters of openings that appear to be related (i.e. interconnected) and count these as individual burrows (= burrow systems). Simple burrows are linear. More complex burrows are T-shaped with three openings and may be further elaborated. Openings/tunnels that are orientated in a different direction are likely to belong to a separate burrow.

5) Some burrow systems are complex conjunctions of the tunnels of an adult and one or more juveniles. Such burrows should be counted as a single burrow."

2.3.2 Visual Fast Count (VFC)

Visual Fast Count (VFC) (Strong *et al* 2006; Barry and Coggan 2010) is a rapid counting technique used to analyse video data. If processing time is an issue due to time or budgetary constraints on the project, but it would be highly useful to obtain counts from the data, then this method can be recommended. Equally, the method ensures that the entirety of the video is analysed, as opposed to small sub-sets, so rare species are less likely to be ignored. This method has also been observed to perform well where the visual field is not of a constant area.

- The video first needs to be split into equal segments (approximately five segments, although this can vary between lengths of tow used).

- Segments are then analysed in a random order to prevent potential biases towards the first segment.

- Once a taxon has been enumerated in a segment, it is not enumerated in any further segments.

- Taxon counts are then multiplied by a weighting factor which is determined using the formula - total number of segments / segment number in which taxon is first observed. This gives the value for that taxon for the whole tow. For example, if there are five segments and a taxon is observed and counted in the first segment then the count is multiplied by 5 (5/1). If the taxon is observed in the second segment then the count is multiplied by 2.5 (5/2), and so on.

- Estimators can then be applied to the counts to account for biases (see Barry and Coggan 2010 for further details).

This method has been shown to be up to 3 and 2.5 times more efficient on rocky reef and gravel substrata respectively when compared to other enumerating techniques (Barry and Coggan 2010). Efficiency was based on the time taken to analyse the first segment, where all taxa are enumerated, in relation to following segments and the total analysis time. It is recommended that this method, as stated by the authors, is used only if the substrata remain similar throughout the entire transect (at least at EUNIS level 3).

Barry and Coggan (2010) detail the biases associated with the method and indicate that the bias will be greater for rarer species. If there are only a few very common taxa and they are present along the whole transect then it may be reasonable to estimate the abundances of these species using a VFC method but to count all occurrences of the other taxa. If all taxa are likely to be rare then is recommended that the VFC method **should** not be used, where potential biases introduced through the VFC methodology will outweigh any time saving associated with not counting all individuals in the transect.

3 Still image analysis

Imagery collected by stills cameras is generally of a higher resolution than the equivalent from video cameras. Consequently, this usually enables the extraction of higher resolution data. For example, van Rein *et al* (2012) showed data from stills imagery to contain more than three times the number of positively identified taxa than that from the equivalent video imagery collected from the same sampling area. The field of view can often be fixed or calculated with stills imagery, which enables the extraction of quantitative data. Still images generate an additional, although not independent dataset from the video. The same epifaunal communities are sampled but in different ways (in terms of area covered and image resolution). Still images can be particularly useful if looking to investigate the role of certain environmental variables and the epifaunal communities. For example, the single field of view allows for the percentage cover of each substratum to be more accurately determined than from a moving video. How these values change with the epifaunal community can then be analysed, e.g. the percentage cover of boulder reef as opposed to bedrock reef.

Still images can assist with the identification of taxa such as sponges, bryozoans and hydroids that can be difficult to identify from video footage. Caution **should** be taken with regards to these taxa where specimens and microscopic analysis may be required to identify these species accurately. However, it can be common for still images to enable a finer taxonomic level to be assigned when compared to video. The more powerful lighting of a stills camera strobe may reveal colours that are difficult to discern on video footage. This may prove particularly important when looking for calcareous algae, for example, the numerous species associated with maerl beds, or particular sponges. While still images may occasionally be used to assist in the identification of organisms from video, analysts must be cautious. A corresponding still image allowing a positive ID of an organism in the video may not necessarily mean the same ID can be placed on what the analyst thinks is the same organism further in the video (without a corresponding still image).

Still images can also be highly useful in assisting with determination of substratum type, where the increased resolution can help to give a clearer image of the finer particles when compared to video imagery. This can help assist with biotope determination (Section 2.2.4). Additionally, information from still images can be used in novel ways, such as determining condition of certain species, e.g. *Eunicella verrucosa* (Annex 5).

If video is available, each still image **should** be assigned to the “parent” video segment. For each image the time and position it was taken **must** be noted (including where the position relates to, e.g. vessel Central Reference Point (CRP), Ultra-Short Baseline System (USBL), or layback calculation) using information from the associated video overlay or from survey metadata. If only a sub-set of still images are analysed this **must** be justified in the survey analysis proformas.

Capture of still images can be carried out using different methods:

1. Purely automated, taken at pre-defined intervals,

2. Manually operated, taken as close to a defined time interval as possible. This allows for operator discretion if the seabed is not in focus at the exact predefined time,

3. Manually operated, taken opportunistically (“opportunistic still images”). This allows capture of specific high quality images of target species or habitats (e.g. *Eunicella verrucosa*, Annex 5).

Still images taken at regular, predefined intervals **must** be statistically analysed separately from opportunistic still images. The common use for opportunistic still images is to assist with organism identification or to gain a more complete understanding of a particularly rare or patchy habitat which is of specific interest.

Still images analysis packages **must** allow the ability to read a variety of RAW files, provide the option to save images as uncompressed TIFF files, and enable the creation of grid overlays.

3.1 Still image analysis methods

Still images **should** be viewed at 100%, or greater than 100% magnification. Analysts must record the physical and biological characteristics present such as substratum type, seabed character, species and life forms.

3.1.1 Image quality

Image quality **should** be assessed before analysis is undertaken. A number of criteria can be used to determine image quality including:

- Camera distance to seabed;
- Lighting quality;
- Angle of the field of view of the camera;
- Focus of image;
- Exposure of the image;
- Level of turbidity.

Example images of poor quality are shown below in

Figure **6**. As with video, if the quality of the images is deemed poor or worse, it is recommended that those images **should** not be analysed further.

Example categories can include:

- ***Excellent*** – Image is clear and fully focussed. Colour and exposure are excellent. Images are generally in field of view categories 2 or 3 (see Section 3.1.2). All levels of analysis are expected to be possible;

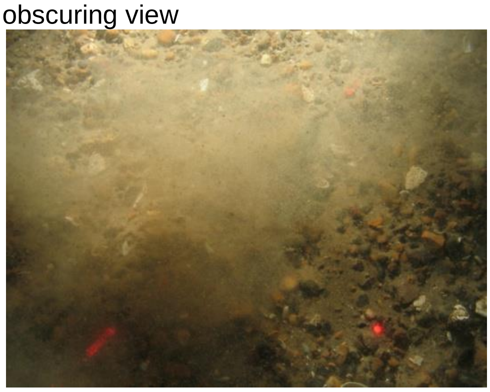
- ***Good*** – Image is in focus but may be slightly over or under exposed. There may be small amounts of suspended matter. Images are generally in field of view categories 1 to 3 (see Section 3.1.2). Small and cryptic taxa are still expected to be visible at this level;

- ***Poor*** – Some elements of the image may be in focus but other aspects such as illumination, turbidity, exposure or the angle of the camera are not ideal (e.g.
- Figure **6**a-c). Images may fall into various field of view categories depending on the issue (see Section 3.1.2). Uncertain if all target objects can be accounted for. Conspicuous taxa may be enumerated but small and cryptic taxa are likely to be missed;

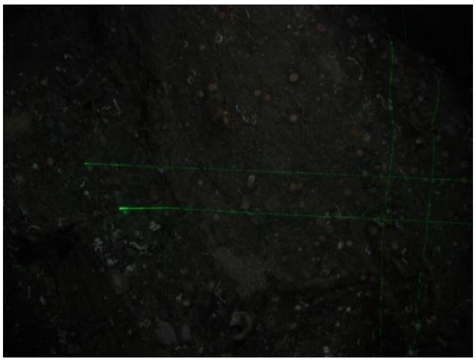
- ***Very Poor*** – Image is predominantly blurred either due to suspended matter or unfocussed (e.g.
- Figure **6**d-e). Images are generally in field of view categories 1 or 4 (see Section 3.1.2). Organisms are unlikely to be distinguished. Broad scale habitat may be determined in some cases.

- ***Zero*** - No view of the seabed at all due to significant over exposure or the camera is too far from the seabed, e.g.
- Figure **6**f. Images not usable.

a) Wash from the camera landing on the seabed obscuring view



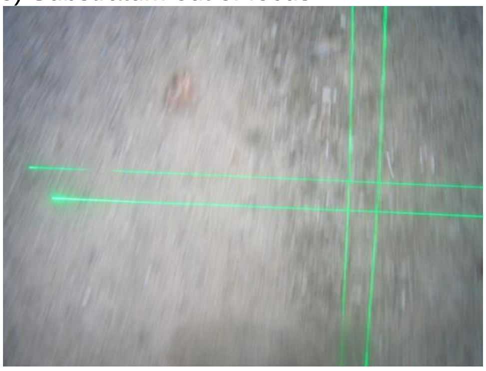
b) Image not sufficiently illuminated



c) Angle of camera not perpendicular to seabed

d) Camera too high above seabed

e) Substratum out of focus



f) Poor visibility

Figure 6 Example still images highlighting potential issues with image quality.

3.1.2 Determining still image field of view

Imagery acquired using sledge systems has constant field of view (which can be calibrated before the survey) as the camera maintains a fixed distance from the seabed. This field of view can be applied to most still images acquired. If images were taken where the sledge was not on the seabed, e.g. over an area of increased rugosity, then these images **should** be excluded from the analysis.

If the height of the camera above the seabed is variable (common with imagery acquired using drop frames) and laser scaling is used (as recommended in the Operational Guidelines; Hitchin *et al* 2015) then the field of view can be calculated on an image by image basis. The distances between the laser scalers can be used to measure still image dimensions. A drop-weight can also be used to assist with this (as detailed below) although its use can result in the obstruction of the field of view in the still images and video.

The field of view of still images collected using drop frames is likely to be variable. Images can be placed into one of five classes, based on the distance to the seabed, to assist with estimating field of view. These categories have been developed for when a drop weight is used;

Table **3** shows average still image dimensions for each category.

- Category 1: The drop-frame is sitting on the seabed and the camera is, therefore, at its closest to the seabed. The weight and rope (if in use), normally suspended below the drop-frame, are not visible within the image. Images are typically slightly or very over-exposed but taxa and substrata (if not too over-exposed) are clearly visible, including small and cryptic taxa.

- Category 2: The weight is visible and clearly on the seabed, usually lying on its side and the rope was slack or also partly lying on the seabed. Images are well lit and taxa and substrata clearly visible, including small and cryptic taxa.

- Category 3: The weight was on the seabed and the rope was tight indicating the camera is the length of the rope (often approximately 1.25 m) off the seabed. To confirm the weight was on the seabed, little or no shadow is visible beside the weight.

Images are well lit and taxa and substrata clearly visible, including most small and cryptic taxa.

- Category 4: The weight is off but still close to the seabed, indicated by little or no gap between the weight and its shadow (i.e. a gap of less than 1 x diameter of the weight is present). Images are slightly darker but taxa and substrata still visible and identifiable. Small and cryptic taxa can potentially be missed or are unidentifiable from images within this category.

- Category 5: The weight is far from the seabed, indicated by a large gap between the weight and its shadow (maximum of 2 x diameter of the weight). Images are quite dark and this category formed the maximum distance from the seabed that taxa and substrata were considered identifiable. However small and more cryptic taxa were more likely to be missed or unidentifiable from images within this category.

Table 3 Average width, height and field of view of the seabed for still images in each field of view category from a JNCC survey in 2014 using a camera on a drop frame (Goudge *et al* 2016).

Field of View category	Width (cm)	Height (cm)	Area of seabed (m^2)
1. Camera very close, no weight visible	58	44	0.3
2. Weight on seabed, rope slack	83	62	0.5
3. Weight on seabed, rope tight	118	88	1.0
4. Weight off seabed, shadow close	151	111	1.7
5. Darker, taxa visible, shadow gap	201	148	3.0

In summary, three methods can be used to obtain a scale from within still images which a field of view can be calculated from:

1. Laser scalars are clearly visible in the photograph; they can be used as a scale to measure the image dimensions. It can be common for the laser scale to not be visible due to the bleaching effect of the camera flash units.

2. Lasers are not visible and a drop weight is used (or another scale type that is sitting on the seafloor). For images where the weight is both on the seabed and clearly visible (categories 2 and 3 only), the diameter of the weight (or scale) can be used instead of the lasers.

3. Neither lasers nor a drop weight are visible within the photographs (category 1), or where the weight or different scale type is not on the seabed (categories 4 and 5). A scale can be obtained from the video and then applied to the still images. An example is shown in Figure 7.

    a. A screen-grab is obtained from the video within two frames of the still image being taken.
    b. The distance between lasers can be measured in the screen grab (using the number of pixels, Figure 7: yellow arrow) to provide a scale in the video at the same location as the still image was taken.

c. An object such a cobble or boulder that is clearly visible in both the video screen-grab and the photograph can be measured (using the number of pixels the object spans in each image, Figure 7: red arrow and blue arrow).
d. The number of pixels can be related back to the known size (between the lasers) and size can be calculated accordingly.
e. This gives a known dimension in the still image (based on total numbers of pixels), from which the still image dimensions (width x height) can be measured and the field of view calculated.

The assumption here is that the still images and video are either taken from the same camera or from different cameras mounted at the same height on the frame.

Once the field of view has been calculated for each still image then they can be cropped if a standardised sample area is required.

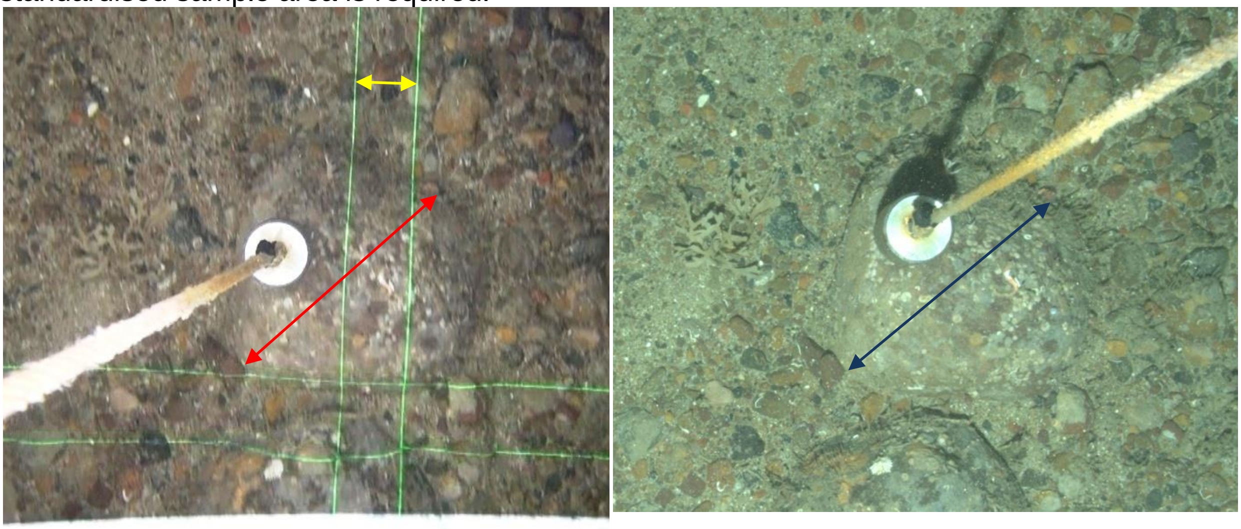


Figure 7 Example of calculating the field of view using method 3 described above. The image on the left shows the video screen-grab (within two frames). The image on the right shows the still image (with lack of laser points or scale on the seabed). Background images ©JNCC/MSS, 2014, actual figures from Goudge *et al* 2016).

3.1.3 Species identification

Species identification from still images should follow the same procedure as for video. See Section 2.2.1. It is possible, but by no means a guarantee, that the increased resolution of still images may allow a finer level of species identification to be obtained.

Where multiple surveyors are working together on a project, a reference collection (further detail in Section 4.2) of still images **must** be maintained throughout the project, particularly for taxa where one analyst is not certain of the identification. Still images (compared to video) are quick to view and allow ongoing regular Quality Assurance (QA) throughout the project to align opinions and minimise discrepancies. It also ensures a minimal list of names and qualifiers (such as sponge morphologies) for unidentifiable taxa, which is important from a species richness point of view.

3.1.4 Determining the abundance of organisms

Procedures for counting organisms described for video data (Section 2.2.2) can also be applied to still images.

3.2 Biotope assignment

It is recommended that biotopes are not assigned to still images as the area is often smaller (see Section 3.1.2) than the smallest biotope size (defined as 5 m x 5 m). The small area covered means that still images are often unlikely to capture all of the species in a biotope or could represent a very small patch of a different biotope within a larger area. Assigning biotopes to still images can lead to confusion when they do not match the biotope of the "parent" video segment.

For example, it is not uncommon for small boulders to occur in an area of mixed sediments. One of these boulders may take up a large area of a still image. This may then be interpreted as a rock biotope (due to forcing a biotope code to such a small area). In this example there is potential for it to be concluded that areas of reef are present when in fact there are only occasional boulders present in the wider sediment biotope.

Still images can be used to assist in assigning biotopes to the video data where the increased resolution may allow for better identification of characterising organisms or substrata.

If it is deemed absolutely necessary to have a biotope assigned to still images, each still image analysed **should** be assigned to the appropriate level of the JNCC Marine Habitat Classification of Britain and Ireland and/or EUNIS hierarchy. If still images are recorded as being different biotopes from their parent video segment then this **must** be included in the analysis notes.

3.3 Specialist techniques

3.3.1 Coral Point Count Software

Tools are now available that aim to provide cover estimates automatically thus reducing the inherent subjectivity of analyst-derived estimates. These software packages, such as Coral Point Count with Excel extensions (CPCE)[14], are now used routinely in analyses of benthic strata (Kohler and Gill, 2006).

A number of tools are available in CPCE. Random points can be distributed across an image and then strata/taxa are identified (Point counts, see Section 2.2.2). A strata/taxa data file can be uploaded or created by the user to enhance the speed of the identification process. In addition to points, if a scale (e.g. laser points) is present, then the image can be calibrated and the area and length of objects can be calculated by the software. Areas can be calculated by tracing around the desired object and the number of pixels is then related

[14] More information can be found and the software downloaded from http://cnso.nova.edu/cpce/index.html

back to the defined scale in the calibration. This can be highly useful to particular studies looking at colony size or patchiness of a taxon /stratum.

CPCE then batch outputs the data to Excel with sheets containing the raw data and a variety of statistical analysis results specified by the user.

3.3.2 Object Based Image Analysis (OBIA)

For particularly large datasets such as those collected using Autonomous Underwater Vehicles (AUVs) where over 250,000 images can be obtained in a single survey, analysts may not have the time to analyse each image individually. This has resulted in the production of algorithms to automatically recognise and assign categories to each image such as identifying the organisms present. Algorithms can be trained to identify organisms of interest using previously collected images based on the Red, Green, and Blue (RGB) values once passed through a variety of filters (e.g. Aguzzi *et al* 2009; 2011; Teixido *et al* 2011; Schoening *et al* 2012).

3.3.3 Photo mosaicing

Photo mosaicing is becoming increasingly popular as technology develops, such as the increased use of AUVs that collect many images on a single deployment. The mosaicing of photographic and videographic imagery is a useful method of creating high resolution imagery over areas of seabed larger than the original image dimensions. Photo mosaics can range in size, from 1m^2 (van Rein *et al* 2011b) to 105,000m^2 (Marcon *et al* 2013), with varying degrees of image discrimination.

The main methods for stitching images together to form a mosaic are: manual, automated feature-based mosaicing and automated navigation-based mosaicing. The automated processes tend to require the application of coded algorithms to the imagery in a processing environment (e.g. Matlab). They differ in that feature-based routines use image recognition algorithms to match and stitch the images together to build the mosaic while the navigation-based routines use geo-referenced navigation data to do so (Marcon *et al* 2013). These are summarised briefly in

Table 4.

Marcon *et al* (2013) describe a tool to create a large georeferenced mosaic of over 5000 images, covering 105,000 m^2. This large-area photo mosaicing (LAPM) tool was developed in Matlab and can create mosaics using both feature tracking and navigation data. The topology is then computed and cross over points are calculated to identify further matches between adjacent images. An optimal transformation matrix for each image is computed via global registration to obtain the smallest global error at the mosaic scale. Once images have been registered they can be merged to form the mosaic via clipping or blending images.

In another application, Marsh *et al* (2013) extracted frame grabs from a video at a rate of 1 image per second, giving a resolution of 960 x 540 px, where approximately every third image was taken forward to create the mosaic. Images were superimposed to overlap with the previous image in the series, and free transformed to give the best possible alignment.

Variations in lighting and shadowing were corrected using the Adobe Photoshop image adjustment settings (Marsh *et al* 2013).

The process of orthorectification, to remove the effects of image perspective and relief, is often applied to mosaic images. This can form part of the normalisation process to give the image a constant scale where features are represented in their true positions. This process requires that the images have accurate spatial data as well as a bathymetry derived Digital Elevation Model. This can be done on a number of visualisation tools, for example ArcGIS.

Table 4 Summary of imagery mosaicing approaches

Approach:	**MANUAL**	**AUTO FEATURE-BASED**	**AUTO NAVIGATION-BASED**
Software used:	Photoshop, Windows movie maker	Matlab	Matlab, Alvin Video Mosaicing Software Suite
Generalised process:	1. Acquire imagery 2. Crop images 3. Normalise images 4. Apply image distortion filter 5. Manually position images correctly 6. Image flattening and blending	1. Acquire imagery 2. Image normalisation 3. Histogram specification 4. Image registration/ matching 5. Cut line selection/blending 6. Mosaic generation	1. Acquire imagery and geo-referenced navigation data 2. Image normalisation 3. Histogram specification 4. Image geolocation 5. Image registration/ matching 6. Cut line selection/blending 7. Mosaic generation
Examples:	Method of van Rein *et al* (2011b). Method of Burton *et al* (2007).	Large Area Photo Mosaicing (LAPM) tool (Marcon *et al* 2013). Method of Elibol *et al* (2011). Method of Lirman *et al* (2007; 2010)	Large Area Photo Mosaicing (LAPM) tool (Marcon *et al* 2013). Method of Rzhanov and Beaulieu (2007)

4 Considerations during analysis

4.1 Organism life forms

Organism life form is commonly considered the most important factor when determining the quantitative enumeration technique for video footage. Due to the complexities of marine organisms there can often be difficulties in determining which enumeration technique is most suitable.

The "Field recording and data management section" of Connor *et al* (2004)[15] is a highly useful aid in determining whether percentage cover or counts are most suitable for enumeration.

The MNCR guidance (Connor *et al* 2004) **should** be followed where it is recommended that encrusting/massive species are enumerated using percentage cover. Solitary colonies that can be easily defined and distinguished, e.g. Solitary sponges (*Axinella*), Sea Fans (*Eunicella*), Sea pens (*Pennatula*), Bryozoans (*Porella*) **should** be enumerated using counts.

For some solitary organisms, e.g. brittlestars and cup corals, abundance can fluctuate in a single survey from single animals to hundreds of organisms. The same enumeration technique **must** be used for each organism for the entire survey and for any subsequent surveys to enable results to be comparable. It is recommended that counts **should** be used for solitary organisms. Where organisms are present in very high numbers across the image then a subsection of the image (1/4th to 1/8th of the image) can be enumerated and then multiplied up to save time if required. This may not be possible if abundance of the organism is not evenly distributed.

Medium to large and massive colonies, e.g. *Alcyonium*, can often be enumerated inconsistently. While *Alcyonium* is named in the MNCR guidance (Connor *et al* 2004) as an organism to enumerate using percentage cover, it could be considered to represent a medium or large solitary organism, where counts would be preferred. It is recommended that a percentage cover **should** be used for these massive colonies as when they occur in high densities it can be difficult to distinguish colonies from one another and colonies can vary greatly in size.

Encrusting organisms **must** always be enumerated using percentage cover as it is generally not possible to identify individual colonies or organisms.

4.2 Reference collections

4.2.1 Taxa reference collection

- A reference image **should** be logged for each species/taxon from the combined video and still image species list for each survey.
- At least one image per species/taxon, either from the video (snapshot/screen grab) or the still images with the preference being a still image due to image resolution.

[15] http://jncc.defra.gov.uk/pdf/04_05_introduction.pdf

- Highlight the species/taxon on the image (e.g. box or circle, see Figure 8) and save the image with the relevant species/taxon name and video/still file name (see Hitchin *et al* 2015).
- Collate information in a spreadsheet that is available to all analysts working on that survey data.

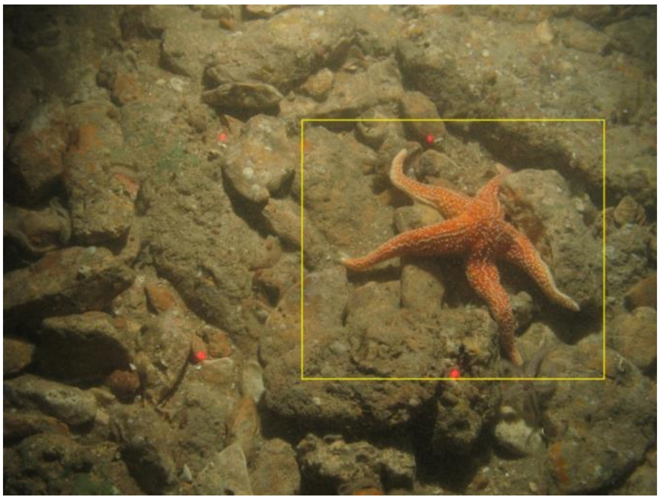


Figure 8 Example reference still image for *Asterias rubens*

4.2.2 Biotope still reference collection

- A reference image **should** be logged for each biotope recorded within the survey. While still images shouldn't be used to assign biotopes (see Section 3.2), a reference image can be manually selected that is most representative of a particular biotope. The image has not been the basis for the biotope assignment itself.
- At least one image per biotope, either from the video (snapshot/screen grab) or the still images with the preference being a still image due to image resolution.
- Save the image with the relevant biotope code, both EUNIS and MNCR, and video/still file name (e.g. Figure 9, see also Hitchin *et al* 2015).
- Collate information in a spreadsheet that is available to all analysts working on that survey data.

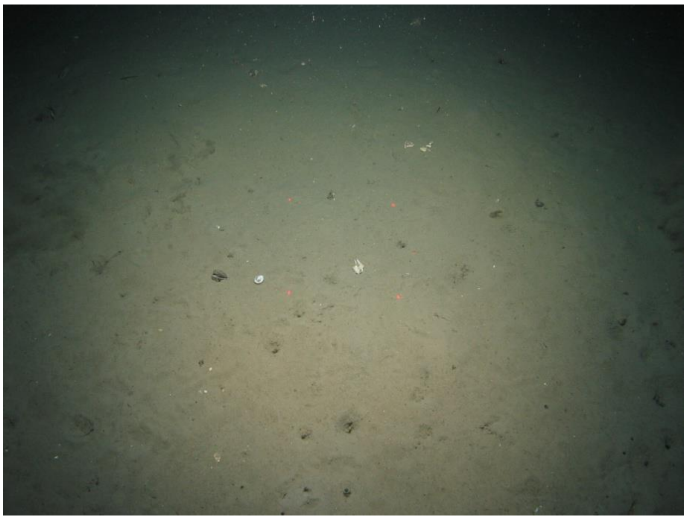


Figure 9 Example reference image for biotope SS.SMU.CFiMu

4.2.3 Biotope video reference collection

- A reference video **should** be logged for each biotope recorded within the survey.
- At least a single 30-60 second video clip per biotope.
- Save the video with the relevant biotope code, both the EUNIS and MNCR, and video file name (see Hitchin *et al* 2015).
- Collate information in a spreadsheet that is available to all analysts working on that survey data.

4.3 Seasonality

It can be important to bear in mind seasonal patterns in the analysis of video and still image data. Optimum seasonal survey times may be present for specific habitats, species or features. While these factors are mainly considered at the survey planning stage, it may be useful to bear in mind the seasonal effects on taxa when interpreting the footage. Many taxa have seasonal growth and reproductive patterns which may significantly alter the number of individuals present at different times of the year. Generally, macroalgal, hydroid and ascidian communities display the most tangible seasonal trends. Biomass and cover generally increase during spring and summer with algae often creating a thick canopy above under-storeys of different fauna and flora (see van Rein *et al* 2011b for seasonality study of harbour wall community monitored with photomosaics).

4.4 Morphology

Species identification from images is difficult and sometimes impossible without physical samples. In these cases, standard visual descriptions based on shape, referred to as morphospecies or morphotypes can be assigned to analyse the communities.

Sponges in particular have been the focus of numerous pieces of work with regards to using morphology to identify the colonies due to difficulties with identifying to lower taxonomic levels from digital imagery (Bell and Barnes 2001; Bell *et al* 2006, Berman *et al* 2013, Haynes *et al* 2014). Details regarding this work can be found in Annex 6.

For deep-sea video analysis, Operational Taxonomic Unit (OTU) numbers in line with the species catalogue developed by Howell and Davies (2010) are often used. The OTU method allows different fauna to be identified as distinct morphospecies – definitely discernible as a different taxon – allowing the final identification of the species to be updated when more definitive ground-truthing data are made available or taxonomy has been agreed. Morphospecies are named according to the finest taxonomic resolution which can reliably be identified followed by species 1, species 2, etc. It is sometimes only possible to consolidate individuals by morphotype – where individuals can only be discerned by a morphological trait, for example encrusting sponges are characterised by colour only given consistent lighting and appropriate pre-processing (Cross *et al* 2014).

5 Archiving data

Digital imagery data **must** be archived appropriately. The highest quality recording (e.g. HD digital video, RAW still images, DV tapes) **must** be regarded as the master copies (as stated within the MESH ROG, Coggan *et al* 2007) and **must** be archived. Ideally data **should** be sent to a data archive centre. Data regarding flora, fauna and habitats **should** be submitted to DASSH[16]. Additional information on data archive centres can be found on the MEDIN[17] website. All data **must** be digitized and backed up on internal servers and/or external hard drives as well as all accompanying metadata. Copies **should** be made as back-ups on portable media (e.g. DV Tape, CD, DVD, etc). Ideally copies **should** be stored off-site or in a fireproof safe if available.

A 'media catalogue' **should** be kept, listing the labels and contents of all recording media (DV tapes, DVDs, CDs, film, etc) produced during the survey. Metadata records from the field record sheet **should** also be transferred to a database.

White *et al* (2007) provide further detail regarding archiving, detailed in the sections below.

5.1 DVD storage

Following the test procedures outlined by the International Standards Organization (ISO), reputable media manufacturers have been able to document data life-spans ranging from 50-200 years. It should be noted that there is a key difference between budget and quality products.

Exposing DVDs to direct sunlight and intense heat can do considerable damage. Rapid changes in temperature and humidity can stress the materials. Fingerprints and smudges can also do more damage than scratches. In order to maximise the life-span of data the following **should** be considered.

Do:

- Handle discs by the outer edge or the centre hole.

[16] The Archive for Marine Species and Habitats Data - http://www.dassh.ac.uk/
[17] Marine Environmental Data and Information Network - http://www.oceannet.org/data_submission/

- Use a non solvent-based felt-tip permanent marker to mark the label side of the disc.
- Store discs upright (book style) in original jewel cases that are specified for CDs and DVDs.
- Store in a cool, dry, dark environment in which the air is clean - relative humidity should be in the range 20 % - 50 % and temperature should be in the range 4°C - 20°C.
- Remove dirt, foreign material, fingerprints, smudges, and liquids by wiping with a clean cotton fabric in a straight line from the centre of the disc toward the outer edge.
- Use deionised (best), distilled or soft tap water to clean your discs. For tough problems use diluted dish detergent or rubbing alcohol. Rinse and dry thoroughly with a lint-free cloth or photo lens tissue.
- Check the disc surface before recording.

Do not:

- Touch the surface of the disc.
- Bend the disc.
- Store discs horizontally for a long time (years).
- Open a recordable optical disc package if you are not ready to record.
- Expose discs to extreme heat or high humidity.
- Expose recordable discs to prolonged sunlight or other sources of UV light.
- Write or mark in the data area of the disc (area where the laser "reads").
- Clean in a circular direction around the disc.

5.2 Magnetic tape storage

Although used less in modern days, if tapes are used then they **must** be of a high quality. Tapes **should** be stored in low humidity environments to promote longer life expectancy.

To maximise the life expectancy of magnetic video tape, the following recommended practices **should** be followed:

- Keep tape away from magnetic fields (e.g. video monitors or loudspeakers).
- Tape storage areas should be cool and dry and not directly exposed to the sun.
- Clean the recorder tape path/heads thoroughly as recommended by the recorder/player equipment manufacturer.

5.3 Marine Recorder Data Entry

In order to keep an accessible record of any data analysed the data **should** be entered into Marine Recorder[18]. Marine Recorder is a database application that is used to store marine benthic sample data. It is fully compatible with the National Biodiversity Network (NBN) data model, enabling data to be contributed to the NBN Gateway[19]. The Marine Recorder manual **must** be consulted. This will identify which fields are mandatory, and where data **must** be input. While the additional fields that are required to be filled in will differ between surveys and clients with regards to data entry the following are also recommended and **should** be followed:

[18]Software, user manual and documentation available as a free download from https://www.esdm.co.uk/marine-recorder and further information can be found at http://jncc.defra.gov.uk/page-1599

[19] https://data.nbn.org.uk/

- Each video tow/drop/transect is classed as a separate “Survey Event”.
- Each segment of video (based on habitat / time / distance) should be entered as a separate “Sample”.
- Each still image, frame grab or different habitat within a tow should be entered as a separate “Sample” linked to the parent video Survey Event. Each event is likely to be made up of several samples including one or more video samples and numerous still image samples.
- Species taxa should be checked against the MSBIAS database otherwise importing data via the Automatic Import tool will not process. A file listing all species in the project species list can be uploaded and checked: http://www.marinespecies.org/msbias/aphia.php?p=match
- Survey dates and full survey methodology information are entered.

There are a number of additional optional fields within Marine Recorder. Whether there is a need for these to be populated will differ from survey to survey and whether stated by any clients.

For further help contact MarineRecorder@jncc.gov.uk

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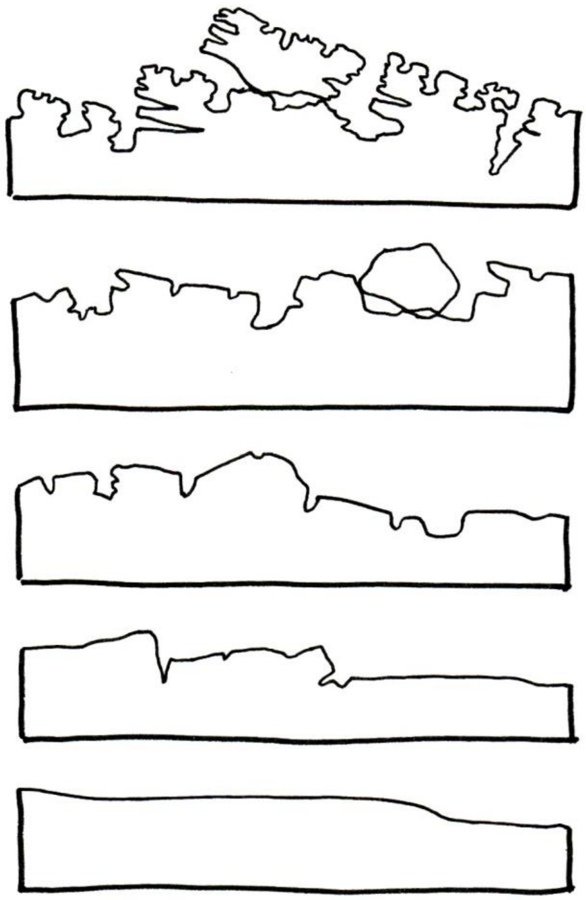
Annex 1: Rugosity

The ‘rugosity’ of a substrate is an indicator of habitat complexity. A ‘Rugosity Index’, on a scale of 0 (no rugosity - *i.e*. flat) to 4 (Extreme rugosity) can be used to aid analysis of substrata during benthic video assessment.



RUGOSITY INDEX

Level 4 (Extreme rugosity)

Level 3 (High rugosity)

Level 2 (Moderate rugosity)

Level 1 (Low rugosity)

Level 0 (No rugosity)

Annex 2: Subtidal broadscale habitat features

Broadscale Habitat Type	EUNIS Level 3 Code
High Energy Infralittoral Rock*	A3.1
Moderate Energy Infralittoral Rock*	A3.2
Low Energy Infralittoral Rock*	A3.3
High Energy Circalittoral Rock**	A4.1
Moderate Energy Circalittoral Rock**	A4.2
Low Energy Circalittoral Rock**	A4.3
Sublittoral Coarse Sediment	A5.1
Sublittoral Sand	A5.2
Sublittoral Mud	A5.3
Sublittoral Mixed Sediment	A5.4
Sublittoral Macrophyte Dominated Sediment	A5.5
Sublittoral Biogenic Reef	A5.6
Deep Seabed***	A6

* *Infralittoral rock includes habitats of bedrock, boulders and cobble which occur in the shallow subtidal zone and typically support seaweed communities*

** *Circalittoral rock includes habitats of bedrock, boulders and cobble characterised by animal dominated communities, rather than seaweed dominated communities*** For deep sea habitats please refer to the JNCC Deep-sea habitat classification and accompanying report (Parry et al 2015)* http://jncc.defra.gov.uk/page-6998

Annex 3. MCZ Habitat Features of Conservation Importance

Habitat Features of Conservation Importance (FOCI)
Blue Mussel Beds (including intertidal beds on mixed and sandy sediments)**
Coldwater Coral Reefs ***
Coral Gardens***
Deepsea Sponge Aggregations***
Estuarine Rocky Habitats
File Shell Beds***
Fragile Sponge and Anthozoan Communities on Subtidal Rocky Habitats
Intertidal Underboulder Communities
Littoral Chalk Communities
Maerl Beds
Horse Mussel (*Modiolus modiolus*) Beds
Mud Habitats in Deepwater
Sea Pen and Burrowing Megafauna Communities
Native Oyster (*Ostrea edulis*) Beds
Peat and Clay Exposures
Honeycomb Worm (*Sabellaria alveolata*) reefs
Ross Worm (*Sabellaria spinulosa*) reefs
Seagrass Beds
Sheltered Muddy Gravels
Subtidal Chalk
Subtidal Sands and Gravels****
Tide-Swept Channels

* *Habitat FOCI have been identified from the 'OSPAR List of Threatened and/or Declining Species and Habitats' and the 'UK List of Priority Species and Habitats (UK BAP)'.*

** *Only includes 'natural' beds on a variety of sediment types. Excludes artificially created mussel beds and those which occur on rocks and boulders.*

*** *Coldwater coral reefs, coral gardens, deep sea sponge aggregations and file shell beds currently do not have distributional data which demonstrate their presence within the MCZ project area.*

**** *The habitat FOCI 'Subtidal Sands and Gravels' is considered to be adequately protected by its component broadscale habitat features, subtidal sand and/or subtidal coarse sediment, and is no longer included within MCZ designations.*

Annex 4: SACFOR

MNCR SACFOR abundance scales

S = Superabundant, A = Abundant, C = Common, F = Frequent, O = Occasional, R = Rare

GROWTH FORM			SIZE OF INDIVIDUALS / COLONIES					
% COVER	CRUST / MEADOW	MASSIVE / TURF	<1 cm	1-3 cm	3-15 cm	>15 cm	DENSITY	
>80%	S		S				>1 / 0.0001 m^2 (1x1 cm)	>10,000/ m^2
40-79%	A	S	A	S			1-9 / 0.001 m^2 (3.16x3.16 cm)	1000-9999 / m^2
20-39%	C	A	C	A	S		1-9 / 0.01 m^2 (10x10 cm)	100-999 / m^2
10-19%	F	C	F	C	A	S	1-9 / 0.1 m^2	10-99 / m^2
5-9%	O	F	O	F	C	A	1-9 / m^2	
1-5% or density	R	O	R	O	F	C	1-9 / 10 m^2 (3.16x3.16 m)	
<1% or density		R		R	O	F	1-9 / 100 m^2 (10x10 m)	
					R	O	1-9 / 1000 m^2 (31.6x31.6 m)	
						R	>1 / 10,000 m^2 (100x100 m)	<1 / 1000 m^2

PORIFERA	Crusts *Halichondria*	Massive spp. *Pachymatisma*		Small solitary *Grantia*	Large solitary *Stelligera*	
HYDROZOA		Turf species *Tubularia* *Abietinaria*		Small clumps *Sarsia* *Aglaophenia*	Solitary *Corymorpha* *Nemertesia*	
ANTHOZOA	*Corynactis*	*Alcyonium*		Small solitary *Epizoanthus* *Caryophyllia*	Med. Solitary *Virgularia* *Cerianthus* *Urticina*	Large solitary *Eunicella* *Funiculina* *Pachycerianthus*
ANNELIDA	*Sabellaria spinulosa*	*Sabellaria alveolata*	*Spirorbis*	Scale worms *Nephtys* *Pomatoceros*	*Chaetopterus* *Arenicola* *Sabella*	
CRUSTACEA	Barnacles Tubiculous amphipods		*Semibalanus* Amphipods	*B. balanus* *Anapagurus* *Pisidia*	*Pagurus* *Galathea* Small crabs	*Homarus* *Nephrops* *Hyas araneus*
MOLLUSCA	*Mytilus* *Modiolus*		Small gastropod *L. neritoides* Small bivalves *Nucula*	Chitons Med. gastropod *L. littorea* *Patella* Med. bivalves *Mytilus* *Pododesmus*	Large gastropod *Buccinum* Lge bivalves *Mya, Pecten* *Arctica*	
BRACHIOPODA				*Neocrania*		
BRYOZOA	Crusts	*Pentapora* *Bugula Flustra*			*Alcyonidium* *Porella*	
ECHINO-DERMATA				*Echinocyamus* *Ocnus*	*Antedon* Small starfish Brittlestars *Echinocardium* *Aslia, Thyone*	Large starfish *Echinus* *Holothuria*
ASCIDIACEA	Colonial *Dendrodoa*			Small solitary *Dendrodoa*	Large solitary *Ascidia, Ciona*	*Diazona*
PISCES					Gobies Blennies	Dog fish Wrasse
PLANTS	Crusts, Maerl *Audouinella* Fucoids, Kelp *Desmarestia*	Foliose Filamentous			*Zostera*	Kelp *Halidrys* *Chorda* *Himanthalia*

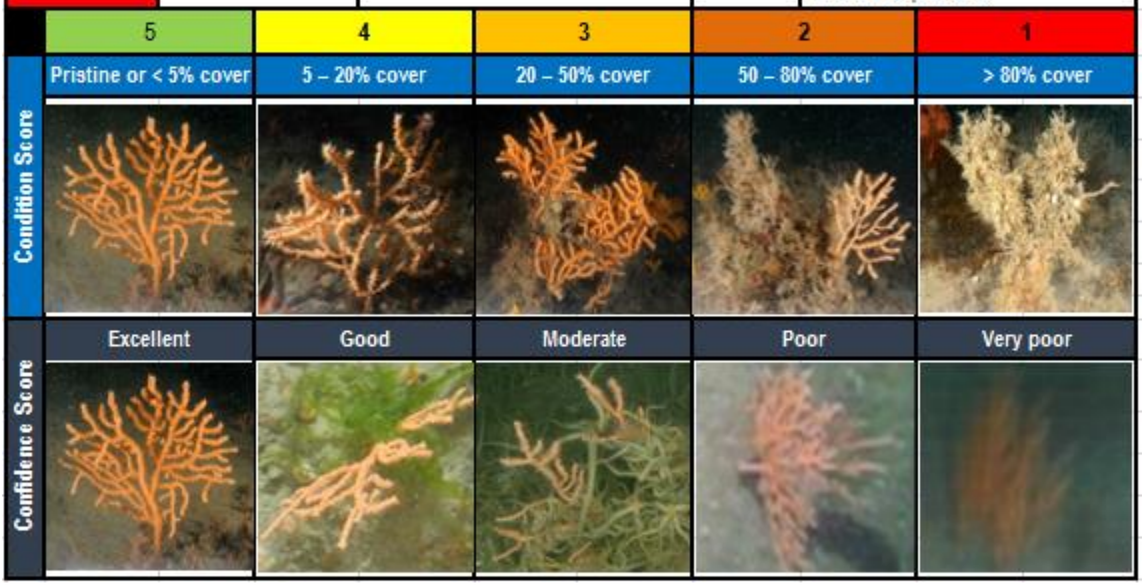
Examples of groups or species for each category

MNCR Notes

- Whenever an attached species covers the substratum and percentage cover can be estimated, that scale should be used in preference to the density scale.
- Use the massive/turf percentage cover scale for all species, except for those given under crust/meadow.
- Where two or more layers exist, for instance foliose algae overgrowing crustose algae, total percentage cover can be over 100% and abundance grade will reflect this.
- Percentage cover of littoral species, particularly the fucoid algae, must be estimated when the tide is out.
- Use quadrats as reference frames for counting, particularly when density is borderline between two of the scale.
- Some extrapolation of the scales may be necessary to estimate abundance for restricted habitats such as rockpools.
- The species (as listed above) take precedence over their actual size in deciding which scale to use.
- When species (such as those associated with algae, hydroid and bryozoan turf or on rocks and shells) are incidentally collected (i.e. collected with other species that were superficially collected for identification) and no meaningful abundance can be assigned to them, they should be noted as present (P).

Annex 5: *Eunicella verrucosa* condition assessment (methods detailed in Ocean Ecology Limited (2015)

Score	Condition Assessment		Confidence	
	% cover	Description	Quality	Description
5	Pristine or < 5%	No epibiota (or hardly any).	Excellent	Whole colony visible and associated species visible (e.g. *Tritonia nilsodhneri*, epibiota).
4	5% - 20%	Partial covering of sea fan by epibiota.	Good	Most of colony visiible, associated species may be visible, suboptimal angle of view.
3	20% - 50%	Up to half of sea fan affected by epibiota.	Moderate	Partially visible, obscured view due to other fauna, accute angle or shadowing.
2	50% - 80%	A large proportion of the sea fan has epibiota covering it, with only a small amount of 'healthy' fan apparent.	Poor	Poor resolution due to blurring, inadequate lighting or turbidy, condition assessment possible.
1	> 80%	Dense cover (almost total) of epibiota.	Very poor	Blurred image or high turbidity, *E. verrucosa* identifiable but no condition assessment possible.



Annex 6: Morphological analysis of sponges

Bell and Barnes (2001), Bell *et al* (2006) Berman *et al* (2013) and Haynes *et al* (2014) discussed the use of morphology for the analysis of sponges on temperate reefs. Morphologies are generally divided into Arborescent, Encrusting, Flabellate, Globular, Massive, Papillate, Burrowing, Pedunculate, Repent, and Tubular (Figure 10). It should be noted that it is not possible to identify the burrowing morphology from imagery alone. Example digital still images are shown in Table 5.

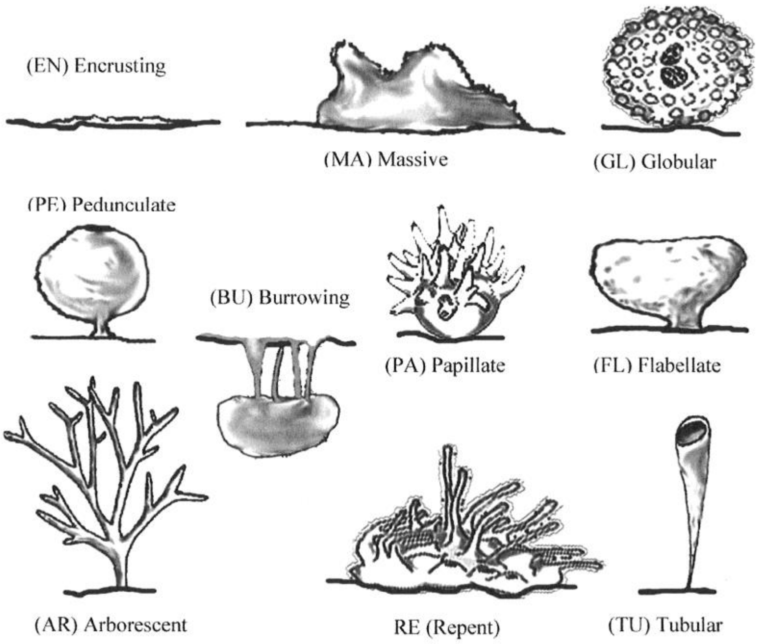


Figure 10 Sponge morphological types (Berman *at al* 2013, after Bell *at al* 2006).

Morphology specific characteristics (Whittington *et al* 2007):

Encrusting:

- Follows underlying substratum.

Massive:

- Forms its own shape (with thickness) above the substratum.
- Arises from a broad base – i.e. not undercut at the edges.
- Surface can be textured (i.e. papillate) but overall shape is more apparent than texture.

Globular:

- Ball-like i.e. rounded.
- Arising from a narrow base i.e. undercut at the edges.
- No peduncle.

Tubular:

- Structure is erect and columnar with a terminal oscule (hole).
- More structure sticking up than at its base.
- Needs to be hollow.

Pedunculate:
- Must have a constricted stalk i.e. a peduncle.
- Structure above the peduncle is 3D and rounded.

Papillate:
- Must have unbranched and distinct papillae arising from a basal structure.
- Base must be joined up between papillae.
- Basal structure can be obscured by sediment.

Flabellate:
- Mostly flattened and unbranched in one plane i.e. 2D.
- Includes vase and cup shapes.

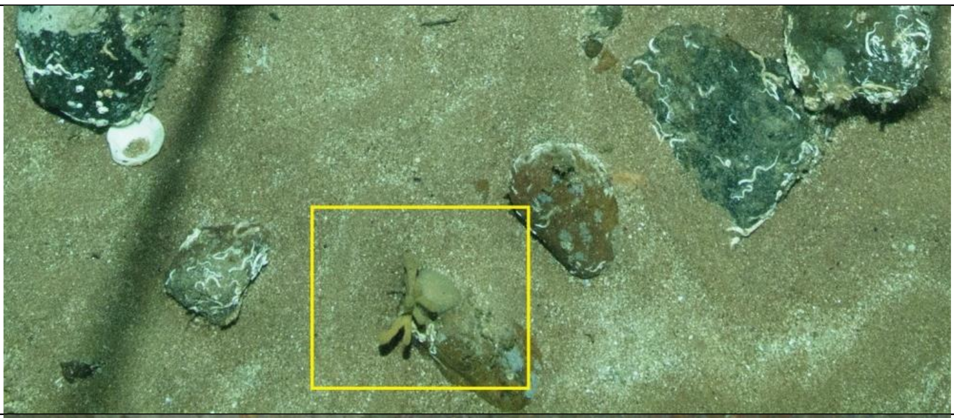
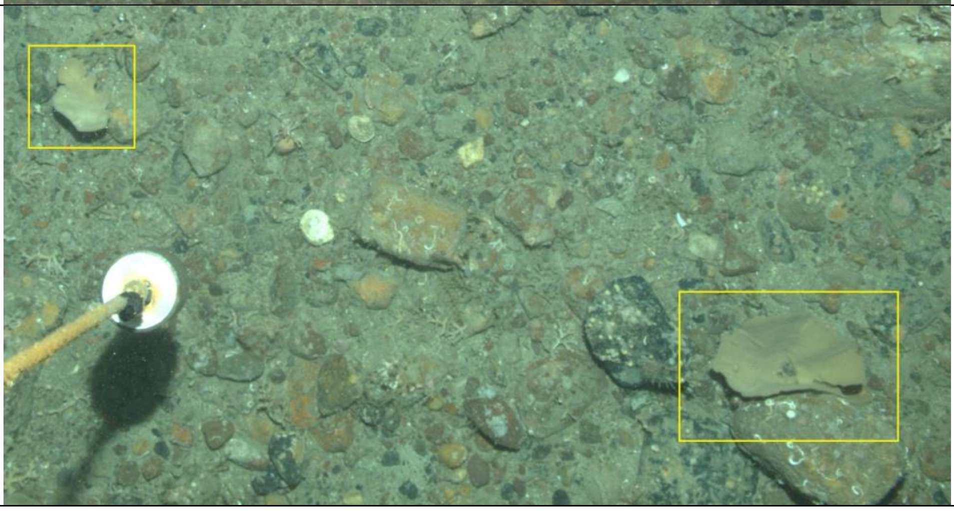
Repent:
- Forms bridges and arches between attachment sites.

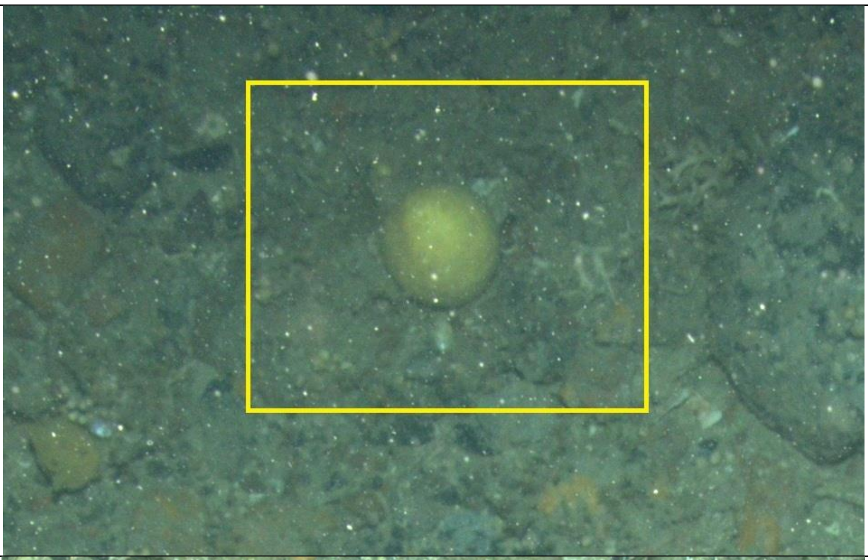
Arborescent:
- Tree or bush-like.
- Does not have to be branching.
- Mostly erect i.e. attachment is only a small proportion structure.
- More 3D branching than 2D.

There are many ways in which sponge morphology data can be analysed (see Berman *et al*, 2013). They can be used to generate univariate statistics (e.g. morphological diversity) and for identifying multivariate patterns in morphological assemblage composition. These data could be treated in the same way as species data.

Moore *et al* (2015) compared *in situ* and using still images using the sponge morphology metric between observers. It was found that pedunculate and globular can often be confused, even *in situ*, if the stalk is not conspicuous e.g. *Suberites carnosus* (Moore *et al* 2015). This was also observed in Goudge *et al* (2016), where it was deemed unlikely the peduncle would be visible, and therefore specimens might easily be misidentified as the globular morphology. Difficulty in identifying morphologies can contribute to the variability in counts being similar for sponge morphologies as those of individual taxa (Moore *et al* 2015). The difference between counts of morphologies from still images and *in situ* records was small. This suggests that morphologies may be an appropriate method of monitoring sponges from digital imagery (Moore *et al* 2015). It is recommended that a note of morphology is made next to each sponge taxon during analysis.

Table 5 Example images of sponge morphologies (from Goudge *et al* 2016)

Sponge Morphology	Example images
Arborescent	
Encrusting	
Flabellate	

Sponge Morphology	Example images
Globular	
Massive	
Papillate	

Sponge Morphology	**Example images**
Tubular