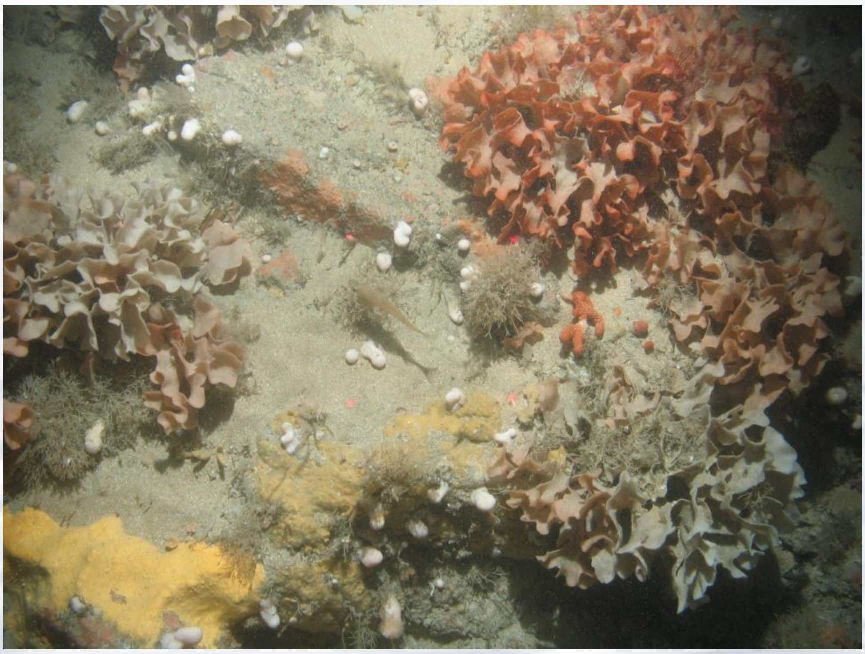
Cefas Project Code: C6124

Epibiota Video Workshop: Summary Recommendations



Version 4

Compiled by: Sue Ware

Issue date: July 2014

Cefas Document Control

Title: Epibiota Video Workshop: Summary Recommendations

Submitted to:	Natural England
Date submitted:	July 2014
Project Manager:	Jackie Eggleton
Report compiled by:	Sue Ware
Quality control by:	Jackie Eggleton
Approved by & date:	Jackie Eggleton (July 2014)
Version:	V5

Version Control History			
Author	**Date**	**Comment**	**Version**
Sue Ware	October 2013	Draft submitted for Cefas QA	1
Sue Ware	November 2013	Revised draft following Cefas QC	2
Sue Ware	January 2014	Revised draft following NE review	3
Sue Ware	April 2014	Revised draft following SNCB review	4
Sue Ware	July 2014	Revised draft following NE review	5

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Issue date: July 2014

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Glossary

BSH	Broadscale Habitat
'Cable Out'	Length of cable between vessel and towed body
Cefas	Centre for Environment, Fisheries and Aquaculture Science
CV	Coefficient of Variation
DC	Drop Camera
Defra	Department for Environment, Food and Rural Affairs
DOENI	Department of Environment Northern Ireland
EA	Environment Agency
EIA	Environmental Impact Assessment
Epifauna	Benthic animals that live on the surface of a substrate of a body of water
EUNIS	European Union Nature Information System
FAO	Food and Agriculture Organisation of the United Nation
FOCI	Feature of Conservation Importance
GAM	Generalised Additive Model
GIS	Geographic Information System
HD	High Definition
IECS	Institute of Estuarine and Coastal Studies
IFCA	Inshore Fisheries and Conservation Authority
Infauna	Benthic animals that live in the substrate of a body of water
INFOMAR	Integrated Mapping for the Sustainable Development of Ireland's Resources
JNCC	Joint Nature Conservation Committee
'Lay Back'	Correction applied for calculation of position of towed body on the seabed
LOESS	Locally weighted RegrESSion
MAREMAP	Marine Environmental Mapping Programme
MBES	MultiBeam EchoSounder
MCZ	Marine Conservation Zone
MEDIN	Marine Environmental Data Information Network
MESH	Mapping European Seabed Habitats
MHCBI	Marine Habitat Classification of Britain and Ireland
MNCR	Marine Nature Conservation Review
MPA	Marine Protected Area
MR	Marine Recorder

NE	Natural England
NMBAQC	National Marine Biological Analytical Quality Control Scheme
NRW	Natural Resources Wales
OAA	Optimum Allocation Analysis
PSA	Particle Size Analysis
PSD	Particle Size Distribution
QA	Quality Assurance
QC	Quality Control
ROG	Recommended Operating Guidelines
ROV	Remotely Operated Vehicle
SAC	Special Area of Conservation
SACFOR	Superabundant, Abundant, Common, Frequent, Occasional, Rare
SAHFOS	Sir Alister Hardy Foundation for Ocean Science
SMPA	Scottish Marine Protected Area
SNCB	Statutory Nature Conservation Body
Steerpoint	Location on the vessel used for positional 'fixing' of deployed survey gear
USBL	Ultra Short Base Line

1 Introduction and Background

1.1 Rationale for the epibiota video workshop

There is increasing awareness that underwater video and stills data are being acquired and utilised by a wide variety of organisations to deliver against an equally wide variety of, often quite disparate, policy objectives. A number of historical guidance documents for the various stages of video and stills data acquisition and utilisation exist but these are considered to be relatively dated.
These include:

NMBAQC Epibiota questionnaire summary:
http://www.nmbaqcs.org/media/9295/nmbaqc%20epibiota%20questionnaire%20review_june%202010.pdf

Development of the NMBAQC video ring test:
http://www.nmbaqcs.org/media/8465/envision%20report%20-%20development%20of%20the%20nmbaqc%20video%20ring%20test.pdf

Procedural Guideline 3-5 JNCC Marine monitoring handbook: http://jncc.defra.gov.uk/PDF/MMH-Pg%203-5.pdf

MESH: Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques: http://www.searchmesh.net/pdf/GMHM3_Video_ROG.pdf

BS EN 16260:2012 Water quality. Visual seabed surveys using remotely operated and/or towed observation gear for collection of environmental data*:
http://shop.bsigroup.com/ProductDetail/?pid=000000000030241897

There is a collective recognition that current guidance documents require revision and updating to achieve the necessary standardisation and adherence to accepted quality standards.

1.2 Aims and Objectives

1.3 Assess whether the existing best practice guidance is sufficient for current requirements for acquisition and interpretation of video and stills data

Across the current policy drivers there is a requirement for the effective acquisition and utilisation of underwater video and still image data by a variety of organisations; e.g., Statutory Nature Conservation Bodies (SNCBs), Inshore Fisheries Conservation Authorities (IFCAs), environmental consultancy agencies and academic institutes.

To effectively achieve the variety of objectives associated with the acquisition of data derived from underwater video and still images, video and still images need to be processed and analysed in such a way that provides a fully comprehensive and standardised output which is suitable for achieving all requirements. These requirements include:

1) **Marine Habitat Mapping** of physical seabed habitats and features in support of a variety of national and international initiatives, e.g., INFOMAR, MESH, MAREMAP.

2) **Characterisation** of epifaunal attributes of seabed habitats and features e.g., in support of the Marine Strategy Framework Directive, Water Framework Directive, designation of Marine Protected Areas (European and National), marine development applications and licensing.

3) **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. This requires the acquisition of comprehensive and standardised data from surveys that can be used to support a range of possible monitoring metrics or derive new ones.

1.3.1 Physical seabed habitat mapping

Seabed habitat mapping initiatives require the translation of spatially comprehensive, remotely sensed acoustic survey data into habitat maps which, as far as possible, accurately describe and classify the seabed habitats and features contained within them. This requires the parallel acquisition of accurately georeferenced 'ground-truth' data (e.g., video and still images of the seabed and associated epifauna, physical samples of seabed sediments and associated infauna) which are of adequate spatial distribution and density to effectively describe and classify the 'signatures' observed in the acoustic data at the required physical and/or biological level.

1.3.2 Biological characterisation of seabed habitat features

Underwater video and stills data are also routinely employed to inform biological characterisation of given physical seabed features and habitats, particularly in relation to rock dominated seabed features where epifaunal communities predominate. In sedimentary habitats, a combination of seabed imagery and sediment grabbing techniques are required to effectively describe both the infaunal and epifaunal components of the associated biological assemblages. Survey design for this purpose requires similar considerations to those associated with physical habitat mapping. For example, an adequate spatial coverage and density of sampling is required to effectively capture variability in biological characteristics both within and between the physical seabed habitats (or strata) of interest.

1.3.3 Detection of change in state of features in support of monitoring

Underwater imagery techniques are also required to contribute to the assessment and monitoring of status (and changes in status) of certain seabed attributes. This requires the selection and development of appropriate metrics or measures (which can be effectively derived from the video and/or still image data) which allow any spatial and/or temporal changes in the status of the physical and/or biological status of the attributes of interest to be detected.

The various univariate metrics (e.g., faunal abundance, species richness, diversity) or multivariate metrics (epifaunal community composition) traditionally employed for this purpose will vary in both their natural spatial and temporal variability. Therefore, the design of a survey intended to detect a given level of change in the given metric of interest (over a given period of time) requires consideration of both the natural spatial and temporal variability in the selected metric to afford the necessary 'power of detection' in the resultant data set. Where several metrics are to be employed to this end, it is advised that the most variable metric is utilised for the purpose of power analyses. This ensures that the survey design will afford the necessary power of detection across the full suite of metrics used.

1.4 Recommendations

Primary Objective:

Clarify where existing standards are sufficient and identify where additional, updated guidance is required.

Current protocols and guidance relating to video and stills data acquisition and analysis require review and updating to inform the development of an 'NMBAQC Best Practice Guidance' document. The updated guidance is not intended to be prescriptive, rather the intention is to enable effective decision making prior to and during survey to enable acquisition of suitable video and stills data for its intended purpose. Outcomes of the epibiota workshop identified that the updated 'Best Practice Guidance' should focus on:

- Identification of examples of current 'best practice'
- Identification of key quality issues from a quality assurance perspective
- The capture of recommendations and knowledge from existing best practice.

2 Video and Stills Data Acquisition

2.1 Summary of workshop outcomes

A number of guidance documents have been developed in relation to best practice for the acquisition of video and stills data. These have traditionally focused on video and stills data acquisition techniques to support and inform characterisation surveys of seabed habitats and their associated epifaunal communities in support of selection and designation of Marine Protected Areas (MPAs).

Guidance documents include:

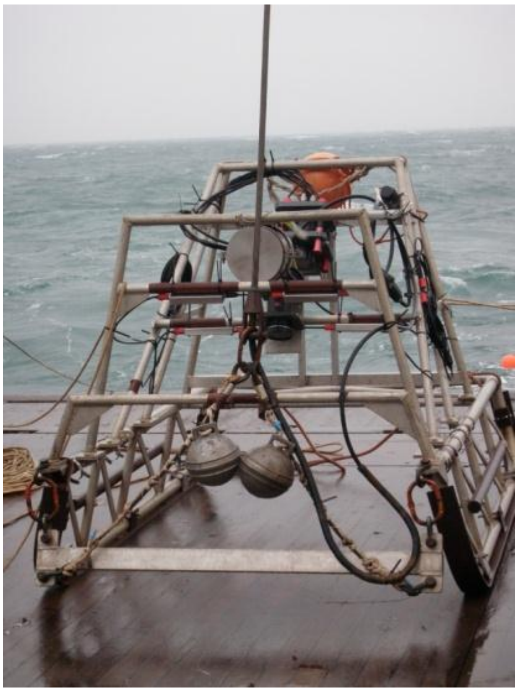
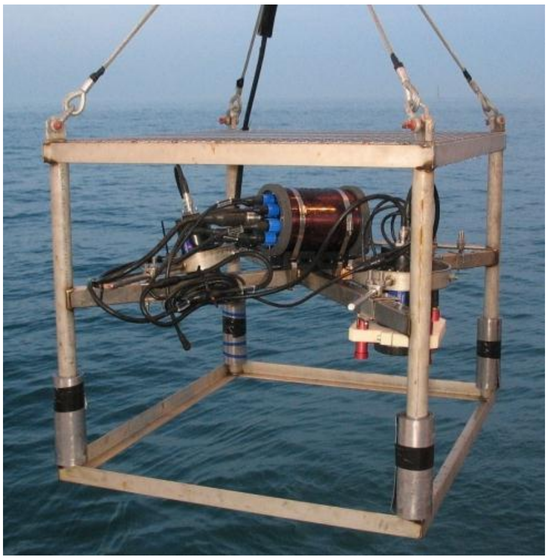
- MESH: Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques: http://www.searchmesh.net/pdf/GMHM3_Video_ROG.pdf

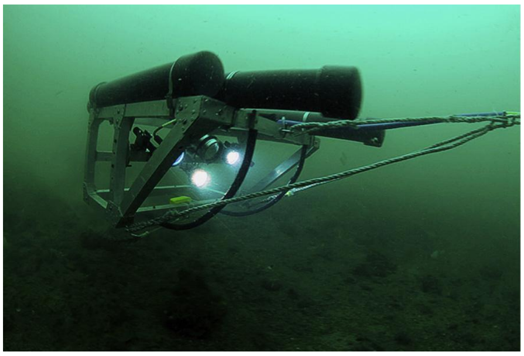
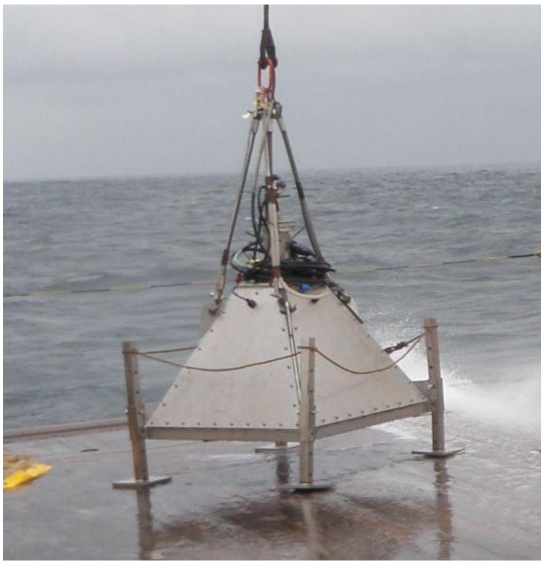
2.1.1 Different equipment setups for different environments (Alex Callaway and David Stephens, Cefas)

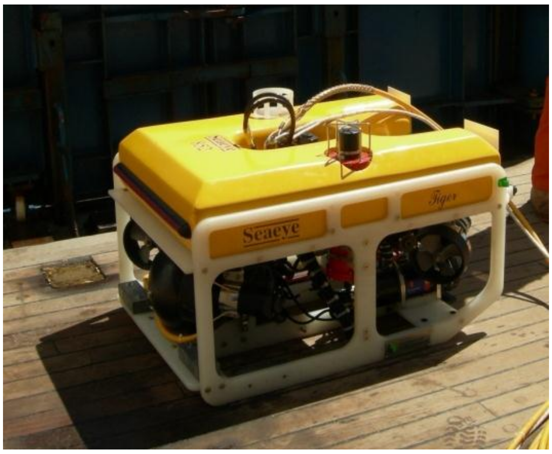
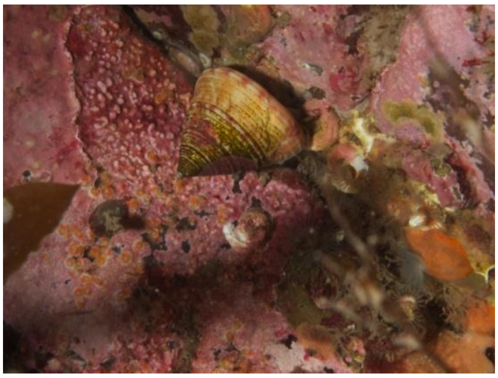
A summary of current methods for the acquisition of video and still image data was provided by Alex Callaway (Cefas). Video and still image acquisition can be achieved using a variety of equipment types (

Table 1). Typically, systems within which the camera is positioned at a fixed height above the seabed (thus providing a fixed field of view) are preferable to 'drop down' units where field of view is variable (e.g., dependant on height of camera platform above the seabed). However, certain practical considerations (e.g., rugosity of the seabed) govern the selection of given camera systems and their configuration.

Table 1. Examples of equipment employed for acquisition of underwater video and still images.

Camera System	Advantages	Disadvantages
Camera Sledge  **©Cefas, 2014**	• Well established and accepted Recommended Operating Guidance (ROG) exists for this sampling device (MESH Reference) • The camera is mounted at a fixed height above the seabed and, thus, allows the field of view to be more stable and fixed	• Limited to use on relatively topographically uniform seafloor habitats • Is in contact with the seabed. Therefore, potential for damage to fragile seabed features and epifauna
Drop Down Camera  **©Cefas, 2014**	• Can be used on a variety of seafloor habitats (including topographically complex upstanding rock and reef features) • Less likely to make contact with the seabed (particularly where sea state is good). Therefore, less potential for physical damage to fragile seabed features and epifauna	• Camera height above the seabed is often extremely variable (particularly in large swell) which, in turn, results in high variability of field of view and thus image quality

Camera System	Advantages	Disadvantages
Flying Array  **©University of Plymouth, 2014**	• Camera is towed at a fixed height above the seabed, thus maintaining a fixed field of view • Does not make contact with the seabed. Therefore, less potential for physical damage to fragile seabed features and epifauna	• As the camera is towed at a relatively high level above the seabed, good visibility through the water column is required to achieve video footage and still images of sufficient quality. However, in poor visibility conditions the camera can be towed closer to the seabed to improve the resultant image quality
Freshwater Lens System  **©Cefas, 2014**	• Increased likelihood of image capture (of sufficient quality) in low visibility conditions	• Limited field of view due to relatively low position of camera above the seabed • Makes contact with seabed, thus potentially causing disturbance to seabed habitats. This also renders the system unsuitable for topographically complex seabeds • Large freshwater prism required renders some systems unsuitable for deployment in poor sea states (particularly from small vessels) • Housing sits closer to the seabed and can result in current flow acceleration, leading to enhanced movement of sediments below the lens

Camera System	Advantages	Disadvantages
Remotely Operated Vehicles (ROV) and Autonomous Underwater Vehicles (AUV)  **©Cefas, 2014**	• Are a variety of systems (with a variety of specifications) which can be employed effectively to meet survey objectives across the range of environmental conditions likely to be encountered • Can be used to 'target' specific seabed features • Non-impact system • Can provide geo-referenced photographic mosaics of the seabed habitats of interest	• Variable/distorted field of view • 'Flight path' largely inconsistent unless re-visiting 'fixed' stations and/or transects of known location • Relatively high cost
Diver Surveys  **©Natural England, 2014**	• Relatively easy to target (and re-visit) specific locations and features (e.g., fixed transects and/or quadrats) • High quality images can be acquired	• Highly affected by environmental conditions (e.g., sea state, currents) • Low spatial extent of resultant data set • Often poor/inaccurate positional information (unless revisiting 'fixed' stations/transects of known location) • Highly variable data quality • Survey area/range restricted by depth • Time restricted

2.2 Key recommendations

Regardless of the camera system and configuration selected for a given survey, there are a number of general recommendations which should be followed during the planning and acquisition phases of underwater camera surveys. These include:

1. **Accurate positional information** for the camera system (and images acquired) during survey is essential. Ideally, this will be achieved through:

    - Use of an Ultra Short Base Line (USBL) device which provides an accurate position of the camera system on the seabed. This is particularly important for towed systems or in strong currents where the location of the camera system on the seabed is likely to be a relatively long distance away from the position of deployment on the vessel (e.g., stern or side gantry).

    - Accurate recording of 'cable out' and ship's heading to enable a 'lay back' calculation to be employed. This will give an estimate of the position of the camera system on the seabed relative to the point of deployment on the vessel (e.g., stern or side gantry).

    - For 'drop down' camera systems, vessel specific positional offsets to the relevant 'steer point' (e.g., stern or side gantry) can be used effectively to achieve a relatively accurate estimate of the location of the camera system on the seabed. However, this estimate will be less accurate for camera systems deployed in deep water and/or in strong currents where the camera system is less likely to be directly vertical to the steer point.

2. **Adequately controlled vessel speed during video and still image data acquisition.** The workshop identified the issue of vessel speed as being key to obtaining imagery of good quality. It was suggested that the 'NMBAQC Best Practice Guidance' document should identify a maximum vessel speed for acquisition of still and video. A possible maximum speed of 0.5kts was suggested by the workshop.

    Adequate control of vessel speed can be achieved using Dynamic Positioning (DP) or, where the survey vessel does not have a DP system, restriction of survey period to suitable environmental conditions (e.g., minimal tidal and wind conditions which will allow data to be acquired during a controlled drift). Vessel speed during data acquisition should be recorded during deployment of the camera system. This allows total length of transect and total area surveyed to be calculated using a combination of the vessel speed and field of view.

It should be noted that some current guidance documents (namely BS EN 16260:2012) recommend an average speed over ground of 1-2 kts during video and still image data acquisition. Outcomes of discussions at the workshop suggested that this speed was considered too fast to allow acquisition of data of sufficient quality for all potential intended purposes.

3. **Accurate time at start and end of transect and accurate time of acquisition of each individual still.** This requires all camera systems to be synchronised with the GPS clock ahead of survey commencing to enable accurate cross referencing of the positional information associated with each image.

4. **Effective lighting.** Lamps should be positioned to minimise the amount of light that is scattered back into the camera lens from particulate matter in the water column, as this can dominate the image and mask the view of the seabed. Backscatter is most intense along the central axis of the lamp, so will be greatest if the lamp is placed close to the axis of the camera. Consequently, the lamps should be set on a different plane to the camera. Angling lights inward will increase the illumination of the water column that can be seen by the camera, and so promote backscatter. Therefore, lamps should be aligned parallel to the axis to the camera, as far as is possible.

5. **Scaling device.** Laser-scaling devices project multiple (typically 4) ‘pinpoint’ spots of known, fixed distance apart onto the seabed, providing a reference scale within the image against which measurements can be made. Where lasers are utilised as a scaling device, tests should be carried out to ensure that the lasers are properly aligned with the central axis of the camera lens and so fall in the centre of the field of view. Lasers are a particularly effective means of providing a reference scale on drop-frames where the field of view varies with the altitude of the camera above the seabed. However, they can equally be used on camera sledges, where the camera usually has a fixed field of view (mounted either vertically or obliquely). A ‘Laser line’ system is also under development which, in addition to providing a scaling device, also provides quantifiable information on rugosity and textural characteristics of seabed substrata.

   Where a laser scaling system is not available for survey, an alternative scaling mechanism (e.g., scale bar) is essential.

6. **Informative camera angle.** Selection of the position and angle of the camera relative to the seabed is often informed by a number of considerations. These include:

    - Minimum required field of view (an obliquely mounted camera system will provide an improved depth of view relative to system facing straight down).
    - Requirement for accurate assessment of field of view. An obliquely mounted camera system will result in a varying field of view across the image due to variability in perspective across the image.
    - Visibility. In poor visibility conditions images of improved quality may be achieved by mounting the camera system closer to the seabed. However, this in turn puts the camera at greater risk of coming into contact with obstacles on the seabed thus increasing potential risk of damage.
    - A four-point scaling device is particularly important in obliquely mounted camera system in order to allow field of view to be accurately calculated where the perspective varies across the image.

7. **Ability to acquire still images**. Whilst there is a continued requirement for video footage (of sufficient quality) to be acquired, the importance of still image data was discussed at some length during the workshop. A number of methods exist for the acquisition of still images of the seabed. These include dedicated utilisation of a stills camera system (with associated strobe or flash), or 'screen capture' of still images from moving video footage. In practice, still images of sufficient quality for both qualitative and/or quantitative analyses are best produced through the use of a dedicated still image camera system (and associated flash) which provides images of sufficient resolution and quality. This will also reduce 'strobing effects' observed when attempting to capture still images from moving video footage.
8. **In depth 'wet testing' of camera system prior to survey commencing.** This allows the camera system and configuration to be adjusted to allow data to be acquired of sufficient quality for its intended purpose.
9. **Adequate briefing of the survey team on the intended purpose of the video and stills data** to enable effective decision making to occur during survey e.g.,

    - Are still image data sufficient for intended purpose?

- At what point are images of insufficient quality for intended purpose? Pre-survey guidance required on when to suspend survey due to insufficient quality of acquired data.
- Are fewer, longer video and stills transects sufficient where speed of vessel limits ability to carry out a greater number of shorter survey transects?
- Frequency of still acquisition at higher vessel speeds to achieve adequate number of still images along a given transect.

3 Video and Stills Data Processing

3.1 Summary of workshop outcomes

A number of guidance documents have been developed in relation to best practice in processing video and stills data. These have traditionally focused on methods of video and stills data processing to support and inform characterisation surveys of given broadscale habitats in support of designating sites (and the features contained within them) as Marine Protected Areas (MPAs) under both International policy drivers (e.g., Special Areas of Conservation under the Habitats Directive) and national policy drivers (e.g., Marine Conservation Zones under the Marine and Coastal Access Act).

Guidance documents include:

- Cefas (2013). Cefas Marine Protected Area (MPA) video and still image processing protocol. 21pp.
- Marine Nature Conservation Review (MNCR) Sublittoral Habitat Recording Form http://jncc.defra.gov.uk/pdf/shabform.pdf
- Coggan, R. and Howell, K. (2005). Draft SOP for the collection and analysis of video and still images for groundtruthing an acoustic basemap. Video Survey SOP version 5. 10pp.

Case studies were presented which summarised how video and stills data had been applied to date in:

1) Physical seabed habitat mapping
2) Biological characterisation of habitat features
3) Detection of change in state of features in support of monitoring

3.1.1 Physical seabed habitat mapping

In general, the main requirements of processing of video and stills data utilised for the purpose of informing acoustic data interpretations for the production of an accurate habitat map are:

Accurate identification and assignment of the habitat features of interest (e.g., substrata, broadscale habitats, habitat FOCI, SMPA search features etc.) at the required level of classification.

Accuracy in the assignment of sediment and feature classification can be improved through:

- **Provision of relevant accompanying data and information** (e.g., PSA results from coincident sediment samples, survey recording forms completed during data acquisition in the field).

- **Provision of adequate training** in protocols and methods employed to achieve sufficient levels of accuracy and standardisation in habitat classification and identification of features of interest.

- **Provision of adequate information resources and guidance** on the agreed data processing protocols to be utilised.

- **Provision of guidance current and accepted definitions of given seabed/habitat features,** particularly those which are more subjective in nature (e.g., stony/cobble reef). This could take the form of a 'library' of video footage and/or still images for given habitat features of interest.

3.1.2 Biological characterisation of habitat features

The majority of studies carried out to date employing underwater video and still image data have largely focused on the characterisation of seabed habitats along with qualitative and/or semi-quantitative analyses of their associated epifaunal communities. A number of case studies were presented which provided detail on how video and stills data are typically processed to inform such 'seabed habitats and epifaunal community characterisation' initiatives. These included application of video and stills data to inform MPA habitat and epifaunal community characterisation (presented by Jackie Eggleton) and a generic overview of video and stills processing methods carried out by Envision Mapping (presented by Alison Benson) and Natural Resources Wales (presented by Charlie Lindenbaum).

3.1.2.1 Video and Stills sample processing in support of MPA characterisation (Jackie Eggleton, Cefas)

The main aims of video and stills image data applications typically carried out by Cefas to date include:

- Identification of presence and extent of given seabed habitat features of interest (e.g., BSH, Habitat FOCI, Annex I Habitats, SMPA Search Features)

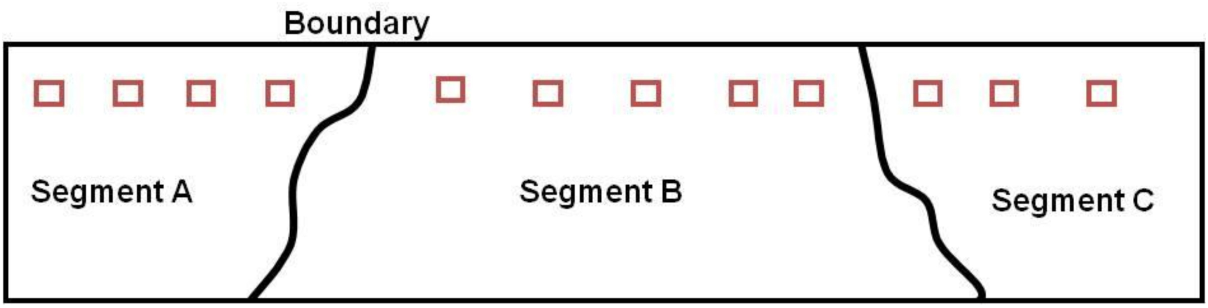
- Identify habitat/feature boundaries

- Provide qualitative and/or semi-quantitative information in relation to associated epifaunal community characteristics

A video and still image processing protocol has been developed by Cefas (in collaboration with partner organisations, namely the JNCC and NE) to improve accuracy and standardisation of approaches adopted to produce these highly informative data sets.

Video processing protocol promotes:

- Initial viewing of video record to allow its segmentation into sections considered to represent different seabed habitat types (N.B., Brief changes in substrate type lasting <1 minute are considered as incidental patches and are not logged as individual sections but are recorded as part of the habitat description)



- Accurate recording of the positions of the start and end of each segment

- Detailed review of each segment to allow a habitat or biotope classification at a level appropriate to the underlying evidence available (e.g., water depth, biological zone, floral and/or faunal community composition).

- Qualitative/semi-quantitative species abundance information (SACFOR) for each video segment.

Stills processing protocol promotes:

- All still images are analysed separately, to supplement and validate the video analysis, and to provide more detailed information than can be extracted from a moving video segment.

- Each image is viewed at normal or greater than normal magnification and physical and biological characteristics (habitat type, counts/percentage cover of species present) are recorded. This allows an appropriate habitat or biotope classification to be assigned to each still image. (N.B., where all still images are analysed it is accepted that given stills may not match the habitat/biotope classification assigned to the 'parent' video segment).

In carrying out video and stills processing using such protocols, a number of issues have been identified. These include:

- Subjective nature of the process (e.g., estimates of percentage cover) often results in high levels of variability between analysts.

- Lack of clarification on the definitions for the many (often varied) features of interest increases potential for variability in the classifications assigned to a given video segment/still image between analysts.

3.1.2.2 Video and stills sample processing methods employed by Envision Mapping (Alison Benson, Envision Mapping)

Envision Mapping have typically carried out video and still image processing to inform seabed characterisation studies in support of Environmental Impact Assessments (EIA) for offshore renewable developments, Marine Protected Areas and associated conservation features (e.g., biogenic reefs), resource mapping (e.g., groundtruthing acoustic measurements of kelp biomass) and resource monitoring (e.g., seagrass beds).

Video processing and analysis software utilised includes Adobe Photoshop, VideoLAN and Pinnacle. This allows:

- Frame capture
- Fast Forward/Rewind control
- Frame by frame progression
- Loop replay

Processing methodology employed depends on the objectives and requirements of the subsequent data analyses. Recent detailed guidance provided by Cefas in support of video and still image processing for 'MCZ feature validation programme' (and provision of useful literature resources/aids, Figure 1, Figure 2 and Figure 3) has proved useful in maintaining consistency in approach between analysts.

	Growth form		Size of individuals or colonies				Density measures					
% cover	Crust or Meadow	Massive or Turf	<1cm	1-3 cm	3-15 cm	>15 cm	No per unit area	Nos per m^2	Nos per $0.5m^2$ image	Nos per $0.4m^2$ image	Nos per $0.3m^2$ image	Nos per $0.2m^2$ image
>80%	S		S				>1/ 0.001 m2	>10,000 / m^2	50,000	40,000	30,000	20,000
40-79%	A	S	A	S			1-9/ 0.001 m2 (1x1 cm)	1000-999 / m^2	5,000	4,000	3,000	2,000
20-39%	C	A	C	A	S		1-9 / 0.01 m2 (10 x 10 cm)	100-999 /m^2	500	400	300	200
10-19%	F	C	F	C	A	S	1-9 / 0.1 m2 (0.316 x 0.316 m)	10-99 m^2	50	40	30	20
5-9%	O	F	O	F	C	A	1-9 / m2 (1 x 1 m)	1-9 / m^2	5	4	3	2
1-5% or density	R	O	R	O	F	C	1-9 / 10m2 (3.16 x 3.16 m)	1-9 / $10m^2$	1	1	1	1
<1% or density		R		R	O	F	1-9 / 100m2 (10 x 10 m)	1-9 / $100m^2$	-	-	-	-
					R	O	1-9 / 1000m2 (31.6 x 31.6 m)	1-9 / $1000m^2$	-	-	-	-
						R	1<1/1000 m2	1<1/1000 m^2	-	-	-	-

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, excepting 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)

Cefas notes

•As the count for individual taxa can never be less than 1 per photo, those in size range >15 cm (e.g. Asterias) can never be scored less than Common in a photo.
•Similarly, size range 3-15 cm (e.g. Echinus) can never be scored less than Frequent and size range 1-3 cm (e.g. Ebalia) can not be scored less than Occasional.

Figure 1. Guidance on application of SACFOR, (modified from Connor & Hiscock, 1996).

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

Figure 2. SACFOR abundance scales (Connor & Hiscock, 1996).

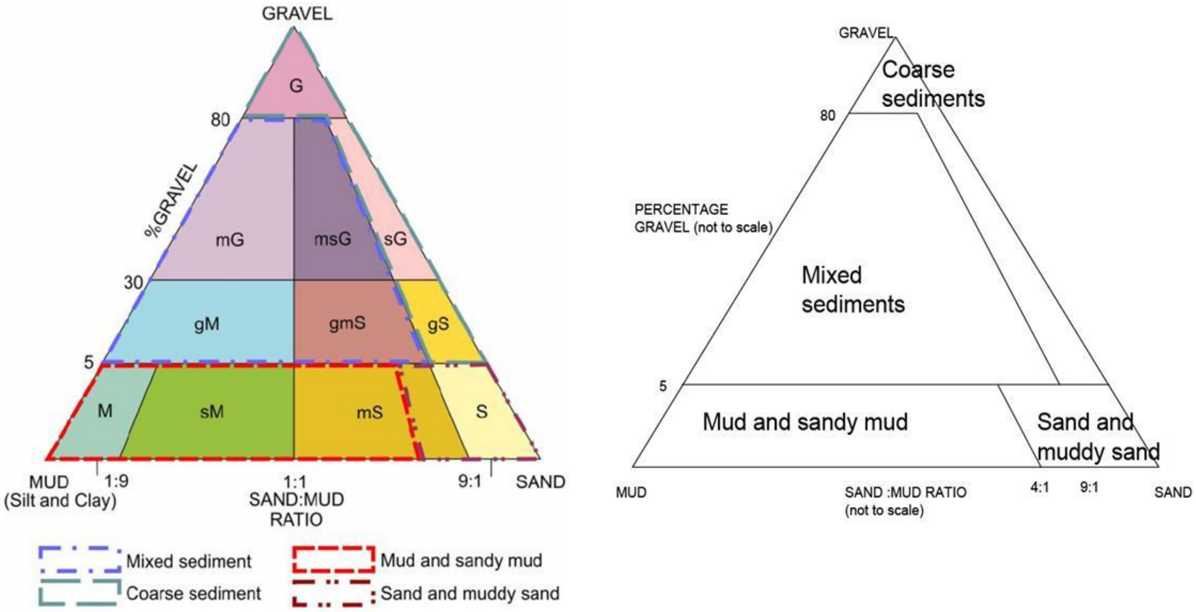


Figure 3. Modified' Folk trigon (left) showing the classification used by the UK SeaMap and MESH projects to assign Folk sediment classes to the four broader sediment classes (right) used in the EUNIS habitat classification scheme (after Long, 2006).

Whilst provision of appropriately detailed protocols (and associated guidance documents) has helped reduce subjectivity in the processing of video and still image data, a number of additional issues were highlighted by Envision Mapping. These include:

Footage/Image Quality:

- Turbidity/visibility
- Lighting configuration
- Height above seabed
- Scale indication

Metadata:

- Issues with missing and/or disorganised metadata
- Inaccuracies in positional information

Accurate Recording:

- Issues with inaccurate biotope allocation
- How should burrows, tubes etc. be recorded when the animal occupying them isn't visible
- Substrate classification (e.g., sediment veneers over rock substrates)
- Identification of species from images alone (e.g., hydroids, sponges etc.)
- Inconsistencies in calculating SACFOR

3.1.2.3 Video and stills sample processing methods employed by Natural Resources Wales (Charlie Lindenbaum, NRW)

Natural Resources Wales have been engaged in carrying out drop down video surveys since 2001 to help inform monitoring in support of the SAC monitoring programme. During this time 'in-house' video and still image processing protocols have been developed to ensure accuracy and consistency in results between analysts. These are similar to those which have been developed by Cefas, JNCC and NE, in that the protocol promotes that:

- Appropriate hardware (e.g., high quality monitor) and software (which can pan forwards and backwards frame by frame as well allowing normal playback at full definition) should be utilised for the purpose of video and still image processing.

- Whole video record should initially be viewed to allow the time and position of any changes in seabed habitat type to be recorded.

- Detailed analysis can then be carried out on each habitat segment to allow accurate classification of the substrata and accurate identification of associated epifaunal species (and, where possible, assignment of the appropriate biotope classification) (Table 2). Abundance of given species is calculated according to the SACFOR scale (using 'field of view' width and approximate tow length).

Table 2. NRW protocol for assigning biotope classifications to underwater video.

Heterogeneity of the Video	Protocol for Assigning Biotope Classification
Recording is of one single, unambiguous biotope representing 100% of the record.	One biotope tag
Record is of two or more biotopes along a transect.	Transect is divided into two or more samples/records. Each record is given one biotope tag.
Key features or species can not be recognised from the video.	The record is tagged with a higher level biotope classification.
The record shows a mixture of two or more biotopes arranged patchily within a single video transect.	The record is tagged with the predominant biotope but the other biotopes present are noted.
The record has features which indicate that it could be regarded as lying between two or more biotope classes.	The record is tagged with the most likely biotope but a record is made as to the issues with the assigned biotope

- A spreadsheet is then populated with the results of the video and still image processing to allow easy input into Marine Recorder.

Whilst the development of appropriate protocols minimises inaccuracy and inconsistency between analysts, a number of common issues with the process were identified. These include:

- **Variable quality of video footage** (e.g., due to tidal currents, seabed topography, sea state etc.).
- **Subjectivity.** May be ameliorated to some extent by use of analysts who participate in NMBAQC scheme (though it is recognised that no scheme currently exists for video and still image processing), along with adequate training.
- **Appropriate guidance, training and QA/QC** (e.g., on methods of assigning seabed habitats and faunal/floral communities to correct biotope classifications etc.).

3.1.3 Detection of change in state of features in support of monitoring

Currently, most video and still image processing protocols do not aim to provide a suitable 'quantitative' data set for application in monitoring to detect change over time. Rather, such protocols have focused on the provision of a suitable 'semi-quantitative' or 'qualitative' datasets which are subsequently employed for the purpose of physical and/or biological habitat characterisation. Jackie Eggleton (Cefas) provided a summary of how such data sets had been produced and utilised for the purpose of characterisation of habitat features (Annex I Rocky reef) at the Isles of Scilly (IoS) SAC.

An example of how video and stills data have been processed to produce a quantitative dataset employed to monitor change in epifaunal communities over time in Lyme Bay was provided by Emma Sheehan (University of Plymouth).

3.1.3.1 Current practices, challenges and successes to date (Jackie Eggleton, Cefas)

The principle objective of the video and still image surveys, conducted by Cefas and the Cornish Inshore Fisheries and Conservation Authority (CIFCA) on behalf of NE in 2011, was to determine the presence, extent and quality of Annex I reef habitats (chiefly upstanding reef, boulder and flat bedrock) within the outer IoS SAC. The video and still image data were acquired from within the SAC using a combination of Remotely Operated Vehicle (ROV) and Drop Camera (DC) systems. Locations of the planned DC and ROV transects were informed using existing acoustic data (namely sidescan sonar and OLEX bathymetry) to ensure adequate coverage across all habitat strata of interest.

Drop down video from all sampling stations were processed (using methods detailed in section 3.1.2.1) and 3 still images, representative of each habitat/biotope segment identified from the video, were also processed. The ROV survey acquired video data only, and only the start and end positions of the video were available. Therefore, accurate positioning of boundaries between habitats along the video transects was not possible. The two resultant datasets provided sufficient ground-truthing information to allow accurate determination of the presence and extent of the upstanding rock reef features within the survey area.

A condition assessment of the Annex I reef features was also conducted as part of this study. This comprised condition assessments of the Bryozoan *Pentapora fascialis* (Ross Coral) and the pink seafan *Eunicella verrucosa*. The condition assessment for the pink seafan was carried out for each individual observed in the video and still image data and employed a 'condition score' ranging from 1 to 5 which was assigned according to the protocol provided below in Figure 4.

Score	% cover	Comment
5	Pristine or < 5%	No epibiota (or hardly any).
4	5% - 20%	Partial covering of sea fan by epibiota.
3	20% - 50%	Up to half of sea fan affected by epibiota.
2	50% - 80%	A large proportion of the sea fan has epibiota covering it, with only a small amount of 'healthy' fan apparent.
1	> 80%	Dense cover (almost total) of epibiota.

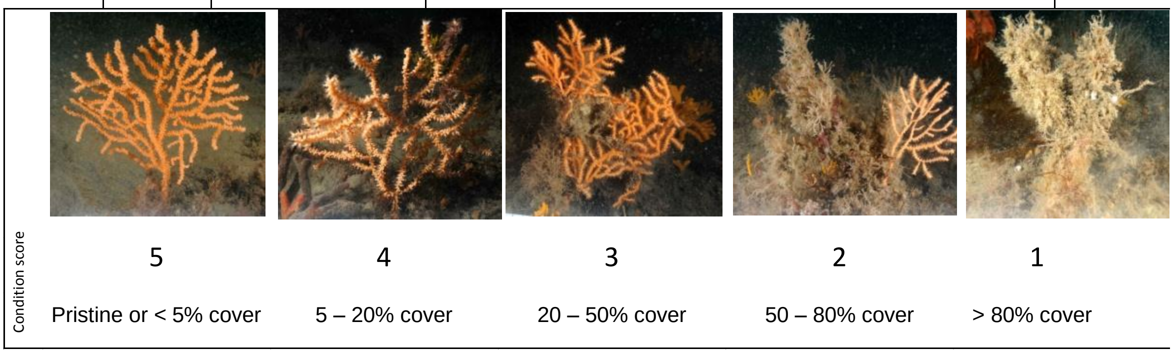


Figure 4. Protocol for assigning a 'condition score' to the pink seafan *Eunicella verrucosa*. (after Wood 2003, based on Irving *et al*.,1996)

3.1.3.2 Drawing lines in the sand: Evidence for functional vs. visual reef boundaries in temperate Marine Protected Areas (Emma Sheehan, University of Plymouth).

The study conducted within Lyme Bay examined the effectiveness of a three year closure to towed demersal fishing in facilitating the recovery of epifaunal communities associated with reef features, and surrounding sedimentary habitats, within the Lyme Bay MPA. A towed flying video array, with High Definition (HD) video was employed for the purpose of this study (Figure 5).

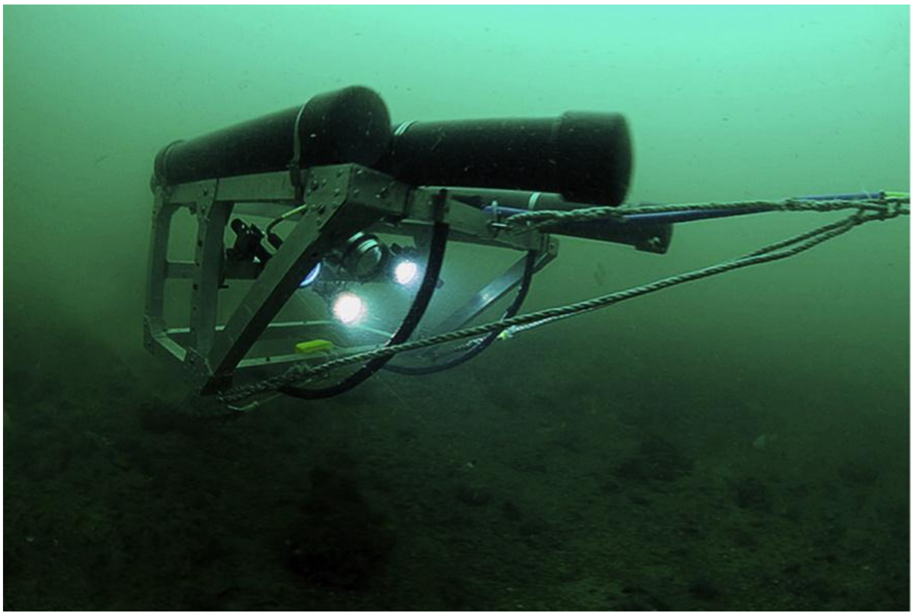


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Figure 5. The towed flying array mounted with HD video.

A number of advantages are afforded by the camera system, these include:

- The camera is 'flown' at a fixed height above the seabed which allows a fixed field of view to be maintained.
- Positioning of the camera at an oblique angle to the seabed (45°) to allow sufficient depth of view in the video and still images.
- Application of lasers, positioned parallel to each other, to allow quantification of field of view.

Species counts were determined by recording every identifiable organism that occurred on the seabed substrate if it passed through the 'gate' formed by the two laser dots. All organisms present were identified to the highest taxonomic level possible and their abundance recorded. Taxonomically similar species which couldn't confidently be identified to species level were grouped according to their morphological traits (e.g., branching sponge, massive sponge).

The area covered by each video transect was calculated by multiplying the length of the tow by the distance between the 'laser gate'. The distance between the laser gate was set according to visibility within the water column, e.g., good visibility=45cm, bad visibility=30cm. This allowed species counts to be calibrated and quantified effectively to estimate density (m^2).

Whilst all taxa were enumerated during video processing, for the purpose of this study, quantitative analyses were only applied to each of the six pre-selected indicator taxa, namely:

1. Ross Coral (*Pentapora fascialis*)
2. Sea Squirt (*Phallusia mammillata*)
3. Dead man's Fingers (*Alcyonium digitatum*)
4. Pink Seafan (*Eunicella verrucosa*)
5. Branching sponges
6. Hydroids

Methods to reduce processing effort for quantitative analyses (Jon Barry, Cefas)

It is recognised that video analysts/processors may not want to count all of the species captured on a video tow. In particular, if the species is very common, quantification may be prohibitively costly and the effort may not be required if adequate precision can be gained from a subset of segments.

One potential method that yields unbiased results for the tow is to sample a random subset of the segments (e.g., sample 2 out of 5 segments). A disadvantage of this approach is that it may mean that 'rarer' species that are only present in unsampled segments will not be recorded.

Another potential approach is known as the 'Visual Fast Count' method. In its basic form this method considers each of the segments in turn (ideally in a random order to prevent potential biases towards the first segment). Once a species has been seen in a segment then it is not counted in any further segments. Visual Fast Counts are multiplied up to get a value for the whole tow. For example, if there are 5 segments and a species is observed in the first segment then the count is multiplied by 5, if the species is first observed in the second segment then the count is multiplied by 5/2. One advantage of this method is that all species present in the tow will be considered and quantified. However, a major disadvantage is that it over estimates the species density (and the bias is worse for rarer species). However, this has been addressed to some extent by application of adjusted estimates when using this method (Barry and Coggan, 2010).

For the purposes of monitoring change over time a number of specific recommendations relevant to the video/still image processing stages were identified. These include:

- **Quantitative processing/analyses** of all epifaunal taxa present along a video transect is likely to be restricted by time required for processing at this level. Therefore, it is recommended that the practicalities of, and potential solutions for, acquiring robust quantitative data (for specific objectives to be effectively achieved) are explored in the developing NMBAQC guidance document. Potential solutions may include focusing on a sub-set of 'indicator species' of interest or employ an accepted method for reducing processing effort (e.g., analysis of a subset of video segments and/or still images, Visual Fast Count methods etc.).

- **Scaling mechanism for standardising field of view** (in both video and still images) is required to allow accuracy in quantification of given measures/metrics (e.g., species density per m^2), particularly for drop down systems where height above seabed is not fixed.

- **Accuracy in ability to calculate length of tow required** to allow accurate quantification of given measures/metrics of interest from video transects.

- **'Opportunistic still images' should not be used for the purpose of quantitative analyses** as they often bias the data towards more conspicuous and charismatic species.

3.2 Key Recommendations

Outcomes of the workshop have identified a number of key actions required, in relation to video and still image processing protocols, for consideration as part of the development of the 'NMBAQC Best Practice Guidance' document. These include:

1. **Requirement for a clear understanding by the video and still image processor/analysts of the objectives and subsequent use of the resultant dataset.** This will allow the processor/analysts to adopt the relevant methodology and protocol to allow production of a suitable dataset for its intended purpose. Furthermore, it will aid the processor in assessing the suitability of image data quality for its intended purpose.

2. **Requirement for accurate and consistent identification and assignment of the features of interest** (e.g., substrata, broadscale habitat, habitat FOCI, SMPA search features, biotope, species etc.) at the required level of classification or taxonomic level. Correct identification and/or classification of features of interest can be improved by:

- Adequate quality of video and still images to allow accurate identification/classification of features to the required level.

- Provision of relevant accompanying information sources to assist in assignment of feature classification (e.g., PSA data for sediments and agreed definitions of habitat features of interest).

- Guidance on appropriate levels of identification achievable using image data alone for given taxonomic groups (e.g., Porifera, Hydrozoa, Bryozoa). Provision of faunal species lists from accompanying ground-truth samples, image library and guidance on identification of key species.

- Appropriate training and provision of suitable guidance on methods and protocols for video and still image processing which is relevant to the given objectives of the study. These may vary according to the ultimate requirement of the resultant data set (e.g., informing interpretations of acoustic data to produce an accurate physical habitat map, biological characterisation of given habitat features of interest, monitoring change in given metrics/measures over time).

3. **Ability to standardise field of view** to allow metrics calculated from video and still image data to be quantified (e.g., density per m^2). This is particularly important where resultant data sets are to be used for quantitative analyses (e.g., for the purpose of temporal monitoring of changes in certain species and/or biological communities). Standardisation of data sets in this way will also facilitate the 'collect once, use many times' principle through allowing spatially and temporally distinct data sets to be compared. This can be achieved by:
   - Operating the camera system at a fixed height above the seabed (e.g., towed camera sledge).

   - Utilisation of appropriate image analysis software to semi-automate/automate standardisation of field of view (using scaling mechanism) and quantification and recording of given species/taxa of interest, e.g., Coral Point Count with Excel extensions[1] (CPCe) (Kohler and Gill, 2006).

[1] http://www.nova.edu/ocean/cpce/

4. **Ability to differentiate still images acquired at a pre-determined time interval from 'opportunistic' still images** taken to focus on particular conspicuous features and/or species of interest. This is particularly important where datasets produced are to be used for quantitative analyses, in that the images used should not be biased towards those particular features/species of interest.

4 Survey Design and Data Analysis

Ecological field surveys often require relatively specialist sampling techniques, data analysis and statistical considerations to afford the necessary 'power of detection' in relation to the many (and often varied) objectives of a given survey. Furthermore, biological data sets rarely conform to the various assumptions required for traditional parametric routines to be applied appropriately (e.g., normal distributions, homogeneity of variance etc). Therefore, in this respect, field biologists are required to have the necessary level of statistical understanding to allow them to design and execute field surveys which will provide the necessary data to effectively explore their hypotheses of interest.

4.1 Summary of workshop outcomes

4.1.1 Physical seabed habitat mapping

Video and still image data are typically used (in conjunction with the results of sediment Particle Size Analysis) to provide a wider spatial context in terms of the characteristics and distribution of broadscale habitats within a given survey area. Video and still image data comprise a valuable component of the necessary ground-truthing data required for accurate classification of signatures in spatially comprehensive acoustic data (using either manual or automated interpretation approaches). Improved accuracy is afforded to such interpretations where sufficient samples are acquired to adequately capture variability within given acoustic facies and also where a sub-set of the ground-truthing data can be excluded from the interpretation to allow subsequent external accuracy tests to be performed on the mapped product.

4.1.1.1 Objective stratification and sampling effort allocation of ground-truthing in benthic mapping surveys (James Strong, IECS)

A summary of methods for optimising the density and distribution of ground-truth sampling points for the purpose of physical habitat mapping was provided. Methods were developed to address the requirement for minimising high financial costs and time associated with collecting ground-truth datasets whilst, at the same time, acquiring a ground-truth data set which is of sufficient density and distribution to capture the variability observed within and between acoustic facies (Strong and Service, 2011). However, one potential disadvantage of this method is that the groundtruthing survey design is reliant on interrogation of the processed acoustic data, and the ability to combine acoustic data acquisition and groundtruthing in the same period of survey may be compromised.

The process described is known as Optimum Allocation Analysis (OAA) which is a method to either 1) allocate sample units to different strata to maximise precision at a fixed cost or 2) allocate sample units to different strata to minimise cost for a selected level of precision.

OAA requires the calculation of both area and variability of a 'population' ('population' is used here to denote a distinct signature or seabed facie derived from an acoustic dataset). Whilst area, in this sense, is relatively easy to calculate, heterogeneity (or variability) is less straightforward. However, OAA provides a mechanism to calculate area and variance from the acoustic data.

An example of the application of OAA in designing a ground-truthing campaign was presented using the North Channel Peaks, Irish Sea, as a case study. Full coverage Multibeam Echosounder (MBES) data had previously been acquired across the survey area to inform the subsequent ground-truthing survey design. Initially, the MBES data were stratified into ground types using Benthic Terrain Modeller. Parameters employed for stratification included MBES bathymetry, slope and backscatter. The area of each stratum was extracted in ArcMap and the variance within each stratum was calculated for the same parameters employed in stratification of the acoustic data. Correlation between variables was examined using an OAA coefficient of variation (CV) set to 5%. Resultant outputs allow optimum density of sampling per strata to be calculated to adequately capture the variability within each stratum. Furthermore, reverse calculation of the CVs with OAA for each ground-truthing parameter (Phi, % silt/clay, BSH type) to explore the significance of different degrees of 'undersampling' during the ground-truthing survey. Furthermore, it allows the relationship between the acoustic data and the measures derived from physical seabed samples to be explored. Results for the North Channel Peaks data indicated that CVs were close to the predicted 5% for video data but less accurate for parameters derived from the Particle Size Distribution (PSD) (e.g., Phi, silt fraction).

4.1.2 Biological characterisation of habitat features

Similar considerations of adequacy in the density and distribution of ground-truthing samples to effectively capture variability in benthic epifaunal communities are required when planning and executing video and still image surveys in support of biological characterisation of habitat features. In doing so, it is recognised that similar processes provided by OAA could be employed to optimise video and stills sampling (for epifaunal communities) and grab sampling (for infaunal communities) across the various seabed habitat features of interest. However, as with the example provided above, in relation to accuracy of physical habitat maps produced for the North Channel Peaks, optimal sampling density can only be achieved where the parameters employed for stratification have an adequately meaningful relationship with the associated faunal measures explored (e.g., variability in the parameters employed for stratification adequately describe the variability in the associated faunal metrics of interest).

4.1.3 Detection of change in state of features in support of monitoring

Statistical robustness in the design of surveys for the purpose of monitoring change over time in epifaunal species and/or communities was considered in a presentation by Jon Barry (Statistician, Cefas).

4.1.3.1 Statistical sampling design: issues for video surveys (Jon Barry, Cefas).

A number of specific topics were considered during the workshop in relation to statistical concepts of survey design for detecting and/or monitoring change over time. These included:

1. General statistical concepts for survey/sampling design
2. Replication
3. Detecting/assessing change
4. Fixed stations (or not)?
5. Current EU guidance

1. General statistical concepts for survey/sampling design

Terminology (using Duke Rock in the Plymouth Sound as an example):

Area=Plymouth Sound
Site=Duke Rock
Station=Video Transect within Duke Rock Site
Replicate=Transect/Segment/Still within Station

Samples and Populations:

Samples should provide information about the population being sampled. In designing a survey to provide accurate information on the 'population' in question the following points should be considered:

- Do you want information about the Area (e.g., Plymouth Sound) as a whole?
- Do you want information about a particular Site (e.g., Duke Rock)?

- Can a given Site be used to make inferences about the Area as a whole?

The choice of Sites within your Area may be on the basis that those are the sites which you most want to monitor (e.g., best examples of the feature of interest). However, the disadvantage of this approach is that the non-randomly selected sites will not give an unbiased estimate of the 'state' of your area over time. An alternative to this is to choose sites randomly (from within your area) ahead of each temporally distinct sampling event (e.g., re-randomise from the pool of potential sites for each survey/sampling event).

Estimation:

The survey/sampling design acts to provide an estimate of one or more of the characteristics of your population (e.g., percentage cover of eelgrass, abundance of a given species or taxon present within a given area/biotope).

The precision of your estimate depends on the variability within your samples and the number of samples taken. Examination of your estimates over time allows you to assess how things are changing over time.

Bias:

On average, is your sample estimate the same as your population estimate?

The Mean squared Error provides the average difference between sample answer and population answer.

Statistical Testing:

Is it plausible that the sample density at two time points could have arisen from a population that is the same in both time points? If the probability of this being the case is very small (as measured by the p-value) then we can confidently conclude that they are different.

In general, you would want your survey/sampling design to have relatively high power (e.g., >80%). However, in designing a survey/sampling strategy to effectively deliver the objectives in question there will always be a balance between cost and power of detection. However, that said, there is little logic in accruing the costs of a survey that doesn't have the power to detect the level of change/difference that you are interested in.

Power of a given sampling strategy to detect change can be calculated in simple cases using standard formulae. However, it is often more effective to calculate power using a simulation exercise (e.g., simulating your design a large number of times and calculating the proportion of times your change is detected). Estimates of the variability within your dataset (to inform the simulation exercise) can be obtained from previous pilot surveys or from other similar datasets.

2. Replication

In the case of a video transect, replicates may comprise video segments and/or still images taken at fixed intervals along the video transect.

Assuming transects are small compared to the overall site, the safest thing to do is to combine the information from all replicates to produce station values as this will act to minimise potential issues associated with spatial correlation and bias. If the numbers of replicates per station are unequal then not doing this will bias summary statistics (e.g., means) towards stations with higher numbers of replicates. However, if the numbers of replicates per stations are equal and if they are not spatially correlated then video segments or still images at fixed intervals along the video transect could be considered to be independent observations or replicates in the subsequent analyses.

Should we maximise on number of replicates or number of stations?

Recommendation is that the number of stations (over replicates) should be optimised. This allows full spatial variability across the site to be captured. If resources dictate that we have sufficient time/budget for N observations, best thing is to have N stations with 1 replicate per station. Choice of ratio of replicates to stations is governed by cost (e.g., transiting between stations, of video /still image analysis). The number of replicates to be employed also depends on relative size of within site and within station variability.

How should station locations be selected-systematic grid or random selection?

Random selection has the advantage that it removes any unforeseen biases such as recording high/low points if the data has some sort of wave pattern. The systematic grid design may be desirable in that it is easier to implement in practice.

Random allocation of stations should give an unbiased estimate for your site (or area). In most cases, a systematic grid (where the position of the grid is randomised) will also do this. However, if the station estimates are to be used in further statistical analyses (e.g., to calculate confidence intervals for your estimates) then spatial correlation between station estimates should be checked (e.g., are stations close to each other more similar than those further apart?).

Spatial correlation within your dataset can be explored using the semi-variogram. For each pair of station estimates, half the squared difference of the measurement of interest is calculated and plotted against the separation distance. The resultant 'variogram cloud' is smoothed by calculating the mean or median semi-variogram value for each of several binned separation distances (Figure 6).

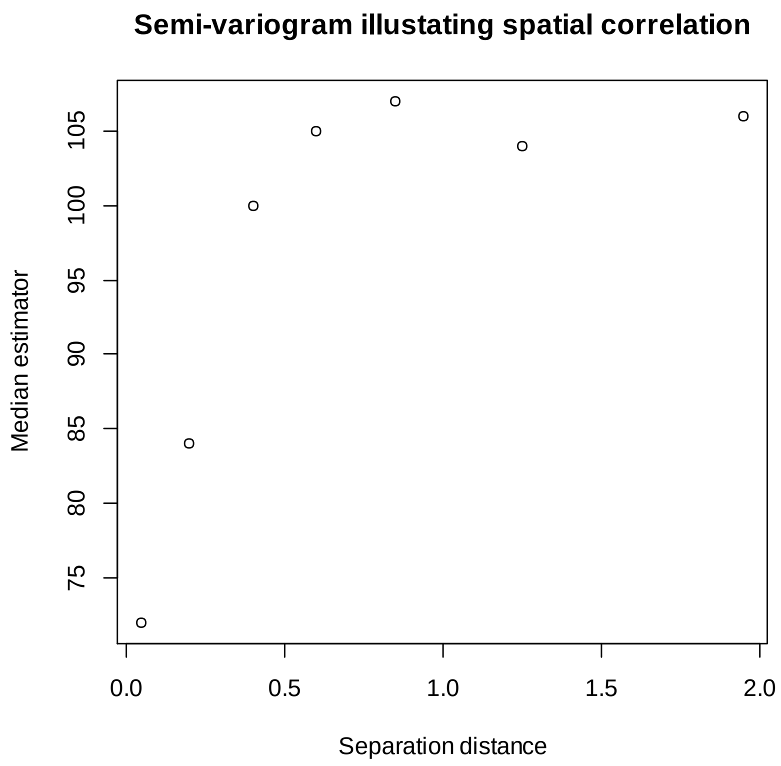

Figure 6. Contrived semi-variogram illustrating spatial correlation up to around 0.7 separation distance.

If the smoothed semi-variogram is constant with time, then there is no evidence of spatial correlation. However, if it rises and then plateaus out to a constant level then the distance at which it levels out can be taken as the distance beyond which points are not spatially correlated.

Parallel/Non-Parallel Transect?

The advantage of parallel transects is that data are potentially more spatially independent (though this depends on the length of transect and separation between stations). The disadvantages of parallel transects include lack of randomness, practical/operational constraints in the field (e.g., effects of tides and currents on direction of travel).

3. Detecting/assessing change

The first step in designing a survey which will allow detecting or monitoring change over time is to:

- Select the measure (or metric) that will define the change (e.g., density of a species per unit area, number of species present per unit area).
- Length of time over which we want to detect change.
- Type/cause of change you want to detect and measure:

  Universal Change=change to your survey area which may also be observed in similar areas (climate change effects). Detecting this type of change would not require a 'control' site.

  Localised Change=change which is specific to your area of interest. Detecting this type of change (e.g., negative effects of trawling, positive effects following cessation of trawling) would require a control site so you can be more confident that your change is the result of localised action rather than some generic change which is happening globally.

Assessing differences between two survey/sampling occasions can be done by comparing the means using a standard parametric t-test, or a non-parametric alternative. Potential candidates for assessing change over longer periods of time include:

- Generalised Additive Model (GAM)
- Smoothing Methods (kernel smoothing, LOESS)
- Linear Regression
- Mann-Kendall Non-Parametric Statistic

4. Power of detection of change

'Power' is the ability of a given statistical procedure to detect change, if it exists. Traditionally, detection of change is defined by whether the p-value arising from a statistical test based on a null hypothesis of 'no change' is less than the critical value (often 0.05). This traditional (conservative) approach, which assumes there is no change unless you have strong evidence of change, is appropriate where remedies required to 'correct' the change are expensive and/or difficult to accomplish. Therefore, you only wish to carry out remediation where you are sure that it is required.

The alternative to this ‘conservative’ approach to detecting change is a more precautionary approach which may be more appropriate where a potential (subtle) change is very damaging. In this instance, less evidence may be required before taking action.

Power to detect change in support of UK marine monitoring programmes has received considerable attention to date (Nicholson and Fryer, 1992, 2002, Maxwell and Jennings, 2005). Power of detection is a function of the **magnitude of the difference**, the **variation in your data** and **sample size**. An example of a power plot which compares changes in the sum of three types of Seapen (Pennatula, Virgularia and Funiculina) is provided in Figure 7. This is looking at the ability to detect potential changes in mean numbers of seapen observed in video data between two sampling occasions in the Fladen SMPA, the second after the implementation of a, hopefully, favourable management regime. It is assumed that counts from stations are spatially dependent and have a negative binomial distribution. The plot shows that the power of detection increases with sample size and also in relation to level of change we are interested in detecting (e.g., for a given sample size greater power of detection will be afforded where the level of change we are required to detect is relatively high).

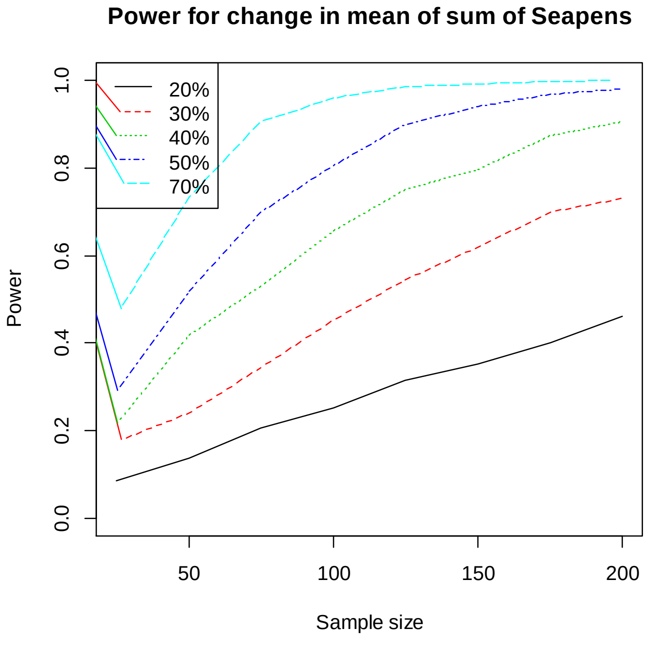

Figure 7. Power plot comparing observations of seapen number from video data acquired in the Fladen SMPA.

4.2 Key Recommendations

A number of key recommendations for survey design in support of accurate physical habitat mapping, benthic characterisation of given habitat features and monitoring change over time were identified.

4.2.1 Physical habitat mapping and biological characterisation of habitat features

1. **Develop and adopt accepted methods for optimisation of density and distribution of ground-truthing sampling points** to ensure adequacy in spatial coverage across all strata of interest (e.g., acoustically delineated facies etc.).

4.2.2 Detection of change in state of features in support of monitoring

1. **Selection of sites within your survey area**

- The choice of sites within your survey area may be on the basis that those are the sites which you most want to monitor (e.g., best examples of the feature of interest). However, the disadvantage of this approach is that the non-randomly selected sites will not give an unbiased estimate of the 'state' of your survey area over time. An alternative to this is to choose sites randomly (from within your survey area) ahead of each temporally distinct sampling event (e.g. re-randomise from the pool of potential sites for each survey/sampling event).

2. **Replication:**

- Assuming transects are small compared to the overall site, the safest thing to do is to combine the information from all replicates to produce station values as this will act to minimise potential issues associated with spatial correlation and bias.
- Number of stations (over replicates) should be optimised.
- Randomisation of sampling stations within your site/strata of interest is desirable over a systematic grid approach. Where a systematic grid design is employed, randomisation of the placement of the grid and consideration of spatial correlation within the data is advocated.
- Selection of parallel orientation of video transect stations within your site has both advantages and disadvantages. Advantages of parallel transects is that data is potentially more spatially independent (though this depends on the length of transect and separation between stations).

Disadvantage of parallel transects includes lack of randomness, practical/operational constraints in the field (e.g., effects of tides and currents on direction of travel).

3. Detecting/assessing change:

Need to consider:

- The measure (or metric) that will define the change (e.g., density of a species per unit area, number of species present per unit area).
- The length of time over which we want to detect change.
- The type/cause of change you want to detect and measure (e.g., universal or localised change)
- Which statistical test/tests are most appropriate for your requirements (multivariate, univariate, parametric, non-parametric).

4. Power of detection of change

Statistical power of your survey design (and resultant dataset) to detect change is a function of:

- The magnitude of the difference you wish to detect
- The variation in your data within/between treatments
- Sample size

Therefore, one of the main outcomes of the workshop was the recognition of a requirement to develop accessible and 'user friendly' methods to assess suitability and power of detection of desired level of change in measures of interest across full range of habitat features of interest. This will involve use of existing data sets (e.g., SAC characterisation and monitoring data, 'MCZ verification' data, SMPA data) to inform on the variability of given metrics within the habitat strata of interest (e.g., broadscale habitats, habitat FOCI) to allow 'generic' power analyses to be carried out in support of future survey design.

5 QA and Best Practice

5.1 Summary of workshop outcomes

It is recognised that a Quality Control (QC) scheme relating to the acquisition and analysis of video and still image data is not currently in place. Whilst a national QC scheme (and associated guidance) does exist for acquisition and analysis of infaunal samples (Hall, 2010, Worsfold et al., 2010), a comparable scheme does not currently exist for the QC of epifaunal data acquired during underwater video surveys.

A presentation, provided by Alison Benson (Envision Ltd.), gave details of a previous initiative which was aimed at developing a NMBAQC scheme for video and still image acquisition and analysis through the application of a 'pilot' video ring test. Further detail on methods for assessing and improving accuracy and consistency in species identification and enumeration was provided in a subsequent presentation by Kerry Howell (University of Plymouth).

5.1.1 Development of the NMBAQC Video Ring Test Pilot (Alison Benson, Envision Ltd.)

The pilot video ring test comprised 3 trial stages.

Test 1 had the primary objectives of:

1. Establishing the general abilities of the participants in video analysis
2. Producing information which will assist in improving and refining future ring tests and associated video analysis guidance documents

In achieving this, participants were sent a standardised data entry form (based on MNCR) and 10 x 1 minute video clips, along with relevant guidance documents and tools to assist in the video analysis exercise.

Assessment of the outputs provided by participants in relation to Test 1 included:

- Analysis of the video clips took a disproportionate amount of time.
- Assessment of the results (which didn't act to 'mark' each analyst but rather assess participant performance against each other) indicated that there was high variability in the results provided across all participants.

Main outcomes/findings identified in relation to Test 1 were:

- High level of variability in degree of experience between analysts (0-12 years).
- High level of variability in the range of equipment utilised for analysis.
- Difficulty in the identification of certain sediment types.
- Lack of clarity in instructions and guidance.
- Poor quality of the video provided.
- Resources which were provided to participants were either not used or missed.

Test 2 had the primary objectives of:

1. Providing a simplified and more focused test (to assess skills in substrate recognition, abundance/coverage estimation, species identification).
2. Testing the effectiveness of using still images.
3. Trialling a ‘marking’ scheme.

Methods employed for Test 2 were revised and refined. Revisions included:

1. The development and provision of a purpose built, online website via which participants could upload their results,
2. Provision of a DVD with 10 x 3 minute video clips with associated metadata,
3. Simplified data entry forms,
4. Revised analysis tools (including new ‘rugosity index’),
5. Provision of two new questionnaires relating to video quality assessment and training requirements.

Assessment of the outputs provided by participants in relation to Test 2 included:

- Test 2 was more refined and straightforward (due to the online results submission process and the design of a test with specific answers).
- There were difficulties in agreeing on an ‘absolute’ correct answer to enable effective ‘marking’ of participants.
- Performance was compared using ‘mode’ (majority) response as a yardstick.

Main outcomes/findings identified in relation to Test 2 were:

- Ability to submit results via website was an improvement.
- An indication of scale (in the video and still images) is required to effectively distinguish between substrates (e.g., sand, gravel, cobble).
- Further guidance/training is required in species identification, substrate classification and methods for accurately estimating abundance.
- Marking the performance of participating analysts is difficult (e.g., what is the ‘correct’ answer?, what is the ‘pass mark’?).
- Use of still images causes analysts to re-assess substrates and marginally improves faunal identification.

Test 3 had the primary objectives of:

1. Refining the online website for submission of results of analysis.
2. Refining the analysis tools.
3. Refining the process for assessing/’marking’ performance.
4. More detailed comparison of methods for estimating abundance/percentage coverage.

Revision of the methods employed for Test 3 included:

1) Refined data entry (making completion compulsory),

2) Further simplification of test to include only substrate recognition and abundance and species identification and abundance,

3) Comparison of methods for estimating abundance/percentage cover, refine analysis tools (rugosity index, SACFOR scale),

4) Application of local/expert knowledge to provide 'correct' answers against which performance can be assessed.

Assessment of the outputs provided by participants in relation to Test 3 included:

- Participants showed some agreement with 'expert' result (often lower than 60%, never higher than 70%)
- Faunal identifications were frequently correct and at a suitable taxonomic level (scores ranged from 56-81%)
- Counts and percentage coverage measures were appropriate for different organisms

Main outcomes/findings identified in relation to Test 3 were:

- Estimates of percentage cover are highly variable between analysts
- Assessment of performance against 'expert' response gives sensible results (but assumes expert is correct)
- Highly variable ability between analysts in accurate identification and classification of substrate types
- Analysts were 'marked' for each element with equal weighting applied (breakdown of scores/marks shown).

The outcomes and findings of each of the tests have indicated that a number of issues, relating to the analysis of video and still images, remain. These include:

1. Improved guidance required on the intended use/application of the results of analysis to enable to the analyst to adopt the most appropriate methods for delivering the required results.

2. Improved guidance required on the assessment of video quality (is the quality sufficient for the intended analysis)?

3. Improved methods required for assessing/marking the performance of analysts.

4. Improved assessment of training requirements across analysts.

5.1.2 Consistency in species identification and abundance estimates (Kerry Howell, University of Plymouth).

It is widely assumed that specimen identification and enumeration by ecologists is accurate and repeatable. However, evidence indicates that this is not the case. Outcomes of a study which explored consistency in the identification and enumeration of marine dinoflagellates from imaged, slide mounted samples found that trained analysts achieved 67-83% self-consistency in identification and only 43% consistency between analysts (Culverhouse et al., 2003). Similar inconsistencies have also been identified in relation to other types of analyses and interpretation, namely in terms of agreement between seabed habitat maps produced using a variety of data types (Cherrill and McClean, 1999, Hearn et al., 2011).

Plymouth University recently carried out an ‘in-house’ assessment of consistency between analysts tasked with the identification and classification of given seabed habitat types (and associated fauna) using video and still image data. The assessment was carried out for up to 4 analysts (with varying levels of experience) between two laboratories. Results of the exercise showed that:

- Consistency was greatest between more experienced analysts and/or those who have worked together for a long period of time.

- Intra-laboratory consistency was greater than inter-laboratory consistency.

- Issues observed were often related to specific taxa (e.g., Ophiuroidea, Actinaria, Porifera).

Main issues and conclusions which emerged from the assessment described above included:

- **Who should be considered as an 'expert'** and provide the results against which others are assessed?

  'Experts' may be considered as those individuals who exhibit high levels of self-consistency.

- **How can consistency between analysts and laboratories be improved**?

  Provision of adequate training and comprehensive guidance resources. It is also suggested that regular inter-calibration exercises (within and between laboratories) should be carried out.

5.2 Key Recommendations

1. **Review and update (where necessary) existing guidance** which relates to the analysis of video and still image data.

2. **Review and update internal QA procedures and reporting of 'actions' against outcome of QA** (e.g., current practise of internal/external QA of 10% of video transects/still images with measures taken to rectify discrepancies between analysts formally reported).

3. **Produce accepted 'Best Practice' guidance** (and associated QC guidance) for application in both acquisition and analysis of video and still image data.

4. **Organise regular workshops** to provide the necessary 'up to date' training and guidance in video and still image data analysis.

5. **Develop and implement a video and still image ring test** which is supported into the future by the relevant centralised management structure (e.g., NMBAQC).

6. **Develop and maintain accepted guidance on habitat classification and definitions underpinned by an up to date 'image library' to aid consistency and accuracy across video and still image data.**

6 Summary of Key Actions

A summary of all of the 'Key Actions' which emerged during the course of the workshop are provided below. Outstanding ,**'Actions'**, in relation to the specific recommendations, are illustrated in **blue text.**

6.1.1 *Video and stills data acquisition*

ACTION: Act to achieve as accurate positional information for the data collected (video and/or still images) as possible within the limits of technologies available.

ACTION: 'NMBAQC Best Practice Guidance' document should identify a maximum vessel speed for acquisition of still and video. A possible maximum speed of 0.5kts was suggested by the workshop.

ACTION: Provide guidance on recommended scale to be employed for given purpose (e.g., identification and recording of cobbles, standardising field of view).

ACTION: Provide guidance on minimum field of view required for given surveys.

ACTION: Provide guidance on quality requirements of still image data and camera systems to be employed to achieve this.

ACTION: Provide guidance which advocates comprehensive pre-survey briefing of survey staff and also thorough 'wet testing' of survey equipment.

6.1.2 *Video and stills data processing*

ACTION: Guidance required on assessing minimum quality required in video and stills data for intended purpose.

ACTION: Development and maintenance of a 'video footage and still image library' to include accepted examples of current habitat feature classifications and epifaunal species of interest.

ACTION: Develop and implement a regular 'NMBAQC video and still image ringtest' (and develop supporting guidance documents and training media as required).

ACTION: Explore techniques for standardising field of view in video and still image data (e.g., development of camera systems which are operated at a fixed height above seabed and/or explore available software which automates retrospective 'field of view' calculation in image data using scaling device).

ACTION: Explore automated techniques for extracting 'regular' still images from 'opportunistic' still images (e.g, automated programme for matching time stamps of still images to associated survey metadata).

6.1.3 Survey design and analysis

ACTION: Develop and advocate use of automated procedures which act to inform density and placement of ground-truthing samples acquired across accompanying spatially comprehensive data (e.g., acoustic data) to inform production of a habitat map.

ACTION: requirement to develop accessible and 'user friendly' methods to assess suitability and power of detection of desired level of change in measures of interest across full range of habitat features of interest. This will involve use of existing data sets (e.g., SAC characterisation and monitoring data, 'MCZ verification' data, SMPA data) to inform on the variability of given metrics within the habitat strata of interest (e.g., broadscale habitats, habitat FOCI) to allow 'generic' power analyses to be carried out in support of future survey design.

6.1.4 QA and best practice

ACTION: Further develop and implement appropriate guidance on QA & QC measures relating to both video and stills data acquisition and processing. This should include guidance on 'remedial' actions to be taken in relation to results of QC and how these should be reported alongside the resultant data set.

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8 Annexes

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8.2 Breakout Session summary

8.2.1 Day 2 Breakout Session (04/09/13): Key gaps in existing guidance and how might they be filled

JNCC lead review of existing practise and guidance identified that current gaps in knowledge and guidance included:

Video and still image acquisition

- Maximum speed of drift/transit during video acquisition (this has implications for guidance on frequency of acquisition of still images along the transect)
- Advantages and disadvantages of given camera systems to facilitate selection of appropriate gear for the objectives of the study.
- Considerations in relation to configuration of camera systems for given purposes.
- Requirement for separate stills camera to prevent loss of video footage during 'real time' review of stills.
- Minimum requirements for data storage and back-up during survey to minimise potential for lost data.
- Metadata to be displayed on video/still image overlay (e.g., date, time, position, Site Code, Station number etc.).
- Use of scaling devices (advocate use of laser scaling devices where possible).
- Type and configuration of lighting sources.
- Detailed guidance for all practitioners (SNCBs, marine developers, academic institutes) to ensure (as far as possible) that data generated follows the principles of 'collect once, use many times'.

Video and still image processing

- Detailed, up to date, guidance on video and still image processing with accompanying guidance on QA & QC procedures (illustrated as a 'decision tree').

- Development of a recording form template to aid in standardisation of reporting of results (incorporating sufficient 'flexibility' to allow it to be employed to meet the full range of potential objectives). Should be Marine Recorder (MR) and MEDIN compliant and allow easy generation of accompanying GIS products.
- Accompanying literature and training media to improve accuracy and consistency in seabed habitat classification and species identification (e.g., image libraries, accepted feature definitions). *N.B., The JNCC are currently drafting supporting guidance documents 'JNCC Guidance-Selecting a Level 5 Biotope' (JNCC, In draft) and 'JNCC Guide Definitions for Substrate Types Used in EUNIS and the Marine Habitat Classification of Britain and Ireland (MHCBI)' (JNCC, In draft).*
- Assessment of suitability of image quality for intended purpose and thresholds for utilisation or rejection.

Survey design and data analysis

- Accepted guidance on experimental design scenarios for given objectives (e.g., pilot surveys, physical habitat characterisation and mapping, monitoring of change).
- 'Generic' power analyses to support survey design (for monitoring) of broadscale habitats of varying heterogeneity.

8.2.2 Day 3 Breakout Session (05/09/13): QA/QC requirements and development of an NMBAQC 'Ring Test'

- Group agreed support for the development of a 'ring test' to be carried out under the NMBAQC scheme ('one off' or recurring)?
- 'Ring test' should be affordable and inclusive.
- Results of the 'Ring test' should act to inform guidance on accepted QA & QC procedures and how to act on (and report) results of remedial actions.
- 'Ring test' could be augmented with additional training forums such as workshops, 'google group', regular Webinars etc.
- Associated guidance documents should be developed and maintained (e.g., guidance on substrate classifications and habitat feature/biotope definitions, image library/catalogue, species image reference collection with guidance on levels of identification and enumeration' possible for given taxon groups).

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