Seafloor Video Mapping:
Collection, analysis and interpretation of seafloor video footage for the purpose of habitat classification and mapping

MESH Video Working Group report

March 2007
CONTENT
This document consists of 87 pages including cover and contents.

This document was published within the framework of MESH, which is an INTERREG III B-NW European Program.

http://www.searchmesh.net/

Reference to this report should be cited as:


† Marine Institute, Ireland
† AFBI/ Queens University Belfast, UK
‡ CEFAS, UK
† Envision Mapping, Ltd., UK.
† JNCC, UK.
Acknowledgements

The MESH Project and Partners wish to acknowledge the funding provided for this work by INTERREG IIIB and match funding from national Partner Organisations, Governing bodies and Research Councils.

The MESH project acknowledges the assistance provided by individuals, institutes, companies and corporate bodies in providing material for these reviews. Wherever possible, acknowledgements have been given to the sources of intellectual property or copyright. Permission to use copyrighted material has been sought, explicitly stating that a null response will be taken to indicate no objection.

Acknowledgement is specifically made to the efforts of the early participants of the MESH video working group input, specifically input from James Strong and Matt Service (AFBI, UK), Jan van Dalfsen (TNO, Netherlands) and Isabelle Du Four (University of Ghent, Belgium).
Commercial Disclaimer

The reviews presented here constitute reviews of generic techniques, technologies and methodology. They are no way intended to be reviews of the efficacy or suitability of commercial products. The reviews necessarily refer to named commercial equipment, systems, software, manufacturers, operators, suppliers etc. Such use of names in no way implies a recommendation for particular branded products, companies, suppliers or software. The exclusion of branded names from the review in no way implies these may be inferior to those mentioned.

Nothing written in these reviews should be interpreted as a product recommendation.
## Contents

1  Seafloor Video Camera Tows For Benthic Habitat Classification .................................................. 1
2  Planning The Survey Strategy – Collection And Analysis .......................................................... 1
3  Camera Use In Turbid Waters ...................................................................................................... 4
4  When To Use Statistical Analysis ............................................................................................. 5
5  Cost-Benefit Analysis Of Varying Qualitative and Quantitative Approaches .............................. 12
6  Discontinuous Habitat Coverage – Sampling Regimes .............................................................. 12
7  Groundtruthing Video Survey Based Upon Acoustic Survey ..................................................... 14
8  Random vs. Structured Sampling Patterns Within A Ground-Type, And Considerations Of Sample Independence .................................................................................................................. 16
9  Random Vs. Structured Sampling Patterns In The Field ................................................................ 17
10 Guidance On The Merits Of Different Tow Lengths For Habitat Mapping ................................... 52
11 Scales Of Acoustic Vs. Ground Truthing Sampling And Positioning ............................................ 53
12 Substratum Classification ........................................................................................................... 55
13 The Extraction Of Semi-Quantitative And Quantitative Species Abundance Data From Video/Photographic Footage: Direct Counts, Visual Fast Counts And Estimates ........................................... 56
14 Using Photographic Stills In Conjunction With Video Footage For Habitat Discrimination ......... 59
15 Database Development ............................................................................................................... 60
16 Interpreting Data For Habitat Classification ............................................................................. 61
17 Statistical Classification Of Seafloor Video Footage .................................................................. 63
18 Georeference Video Footage And Images: .................................................................................... 74
19 Data Storage and Archiving: Vhs Tape/Dvd Longevity Issues ...................................................... 77
20 References ................................................................................................................................. 80
1 Seafloor Video Camera Tows for Benthic Habitat Classification

J. White

Towed video camera surveys of the seafloor have been undertaken by commercial, governmental and research organisations for biological, environmental, geological and industrial applications with increasing frequency over the past 30 years. Advances in technology and decreasing costs are making the approach ever increasingly available. This is of specific value to commercial, semi and state agencies under the pressing European legislation to map, monitor and protect marine habitats.

The quality of seafloor video footage is now becoming cost effectively appropriate for identifying, mapping the extent and determining the quality of seafloor habitats in a timely efficient manner over large areas (Service and Golding, 2001). Footage collected maybe used independently, or in partnership with other surveying approaches, such as species lists and count data from dredges and grab samples, particle size analysis, acoustic surveys using single beam, multibeam and interferometric swath echo sounders or side scan sonar. The MESH Review of Standards and Protocols for Seabed Habitat Mapping (Coggan et al., 2007a), reviews the types of camera and video equipment available in recent and current operation, while the accompanying MESH Video Recommended Operating Guideline (ROG) details a recommended deployment process for underwater video and stills cameras and ROVs for the purpose of seafloor habitat mapping. This report deals with theoretical and semantic issues; discussing the ways in which video and stills cameras may be used as a ground truthing and habitat mapping tools, from purpose and survey design, through deployment to analysis. The report is illustrated with 3 case studies providing examples of issues faced.

2 Planning the survey strategy – collection and analysis

J. White

The approach adopted for a seafloor video survey can be initially summarised into five simple questions:

- what equipment is available and how should it be used;
- where should the video camera be deployed;
- should it be towed in a predetermined direction;
- for how long or how far and;
- how will the footage be analysed.

There are several reviews covering the range of different equipment used for collecting seafloor video footage (MESH Standards and Protocols, 2006; Somerton and Glendhill, 2005; Penrose et al., DRAFT) these will not be detailed here, but summarised to provide context.

Early cameras were often structured to include both the optical and recording device together, tending to be consumer available camcorders encapsulated in watertight pressure housings strapped to a “drop” frame or sled with accompanying lighting. Soon the camera and recording components were being split, with a cable joining the two; providing a live feed to the surface and giving a real-time view of the seafloor. This approach was clearly advantageous, enabling any problems, from pressure...
housing leaks to silt-outs, to be quickly realised and resolved. Examples of the umbilical colour camera and lighting units used in are shown in Figure 1 and Figure 2 and images are given in Figure 4.

![Figure 1](image1.png)
**Figure 1.** Tripod camera drop frame with umbilical direct feed, lighting and USBL positioning beacon.

![Figure 2](image2.png)
**Figure 2.** Side deployed video drop frame (left) and stern deployed towed sled.

![Figure 3](image3.png)
**Figure 3.** Examples of umbilical fed submersible colour video camera (Simrad Kongsberg model E14-366-0005), bulb and LED lighting units and mounting block with camera in the towed sled in Figure 2.

The question of where to deploy a camera will depend upon the purpose of the tow, i.e. to identify a transition between habitats, or assign homogeneity to one habitat. The aims of the tow will also influence the direction of a desired tow, although this also will need to take into account prevailing current, tide and wind. The aims of the survey and anticipated analysis will also likely address the question of how long to tow.
The method by which the footage is collected should be designed to ensure it provides data of a sufficient quality and resolution for its intended purpose. Camera field of view and lighting should be standardised and recorded. If a camera can be tilted while deployed, a “set” position should be standardised for surveying and this tilt position routinely returned to. Some systems, such as the tripod drop frame shown in Figure 1 give different fields of view depending upon their position on the seafloor; standing upright provides a broad field of view (Figure 4), and face down, a close up view of the seafloor (Figure 5). In interpretation, such different fields of view cannot be considered comparable and will need to be dealt with as different data sets.

How raw video footage should be processed once it has been collected will always be contentious subject and will inevitably be a compromise governed by the available processing time, the resolution and quality of the footage and intended objective or subjective analysis. Enumeration for a fully objective quantitative analysis will take much more effort than expert classification to a predetermined classification system, or labelling to site or survey-specific subjective classification.

**Figure 4.** Stills from seafloor video transect with a wide angle of perspective.

**Figure 5.** Stills from seafloor video transect with a narrow angle of perspective showing close up of the seafloor.

While absolute counts can be achieved using pause, rewind, playback and reduced speed play features of video, DVD and PC media storage, the process can be extensively time consuming. Replaying footage once, at normal speed, has been shown to give statistically acceptable accurate counts by accustomed independent observers (Rosenkranz and Byersdorfer, 2004). Several approximation methods, with error estimations, have been developed such as the Visual Fast Count (Kimmel, 1985; Magorrian and Service, 1998 and; Strong et al., 2006). Such approaches may be termed semi-quantitative and are usually adopted to provide meaning full and realistically attainable data in light of processing resources.

Video quality must be accounted for if a quantitative approach is to be taken; the brightness of lighting; the speed of camera across the seafloor and the resolution of
the camera and speed of recording medium can influence the size of organisms' that can be counted and identified to species, genus or family level. The effects from the backscatter of light off suspended particles and fine material disturbed from the seafloor and obscuring the field of view can also deteriorate image quality.

The reduction in viable quantitative footage owing to poor quality should be appropriately dealt with to ensure that comparisons between tows are valid. Several solutions may be adopted: measure the proportion of viable to non-viable footage and apply appropriate abundance multipliers to the data, apply an appropriate transformation to normalise frequency distribution of the data, or alternatively handle data proportionally or as presence/absence.

Analysis may take the approach of sub-sampling a video tow – enumerating biota in randomly selected sub-sections of a video tow. This runs the risk of the randomly chosen sections being of poor quality, in which case a frame jumping technique can be applied, whereby if the footage falls below a defined quality threshold (for example more than 10% of footage is obscured), the section is skipped, moving either forward or backward through the footage to the next analytically appropriate section with quality above the defined threshold (Kenyon et al., 2005).

3 Camera use in turbid waters

While it is not the aim of this report to detail deployment of video cameras which is dealt with elsewhere (Coggan et al., 2006), deployment in turbid water is worthy of note. In shallow areas, affected by strong wave regimes or bottom currents, fine sediment loading in the water column can be substantial, reducing visibility. This clearly presents problems for the use of video by obscuring of the field of view and enhanced light backscatter.

The dragging of camera drop frames and sledges will also disturb fine sediments, reducing visibility. This can be minimised by towing the camera into the prevailing current, so in any disturbed sediment is washed backwards and out of the cameras field of view. This is a good solution where surface currents and bottom currents parallel one another, however in deeper waters where bottom and surface currents and tides may not be concurrent, disturbed sediment can present problems and work may be most productive during periods of slack tide, or when surface and bottom currents are similar.

Enclosed shallow highly turbid waters, such as those of the Wadden Sea and southern North Sea, present interesting situations for video work. Solutions include: working only in slack periods at high or low tide, working seasonally during periods of minimal suspended material for example, usually avoiding initial spring and secondary algal blooms, high inputs from rivers and run off from land, and working in calm weather when wave action is minimal; thereby reducing wave driven sediment disturbance.

To reduce the volume of turbid water in the cameras field of view a “freshwater lens” can be used. The camera is mounted in a housing of freshwater, accounting for a proportion of the cameras focal length, the bottom of which gets close to the seafloor so removing a large portion of the turbid water from the field of view (Figure 6). As the housing is filled with water and allows for changes in ambient pressure, the
integrity does not need to be complete, the face plate, represents a vulnerable point and needs to be resilient against knocks off the seafloor and can be manufactured from polycarbonate sheet or tempered glass.

![Diagram of camera enclosed in a freshwater lens, displacing a proportion of turbid water in the cameras focal length with clear water.](image)

**Figure 6.** Camera enclosed in a freshwater lens, displacing a proportion of turbid water in the cameras focal length with clear water.

## 4 When to use statistical analysis

J. White

Footage from video transects may be defined as providing qualitative through to semi-quantitative to qualitative samples of macro epibenthos and seabed sediments. By viewing the footage, the seafloor can be subjectively labelled or named, based upon the observers experience or international classification systems. For a more objective, quantitative approach, “samples” need to be standardised in as far as is possible to maintain comparability. A sample might constitute the footage from an entire video tow, or a selected section of footage from a video tow. To permit comparisons with other sets or comparable sections, the method used in counting or estimating the numbers of organisms observed, needs to be standard across any sections intended to constitute a data set (or sets). Comparable sections are measured either by the distance the camera travels over the sea floor or substituted for by time (Magorrian and Service, 1998).

Statistics can be a useful tool in processing video footage under a number of circumstances. To simply classify a section of seafloor, statistics may not be necessary at all and comparison with a habitat classification system such as EUNIS (http://eunis.eea.europa.eu/habitats-code-browser.jsp) will suffice. Indeed seafloor classifications have been made totally independent of recognised classification systems based on observations of the video footage and expert opinion (Zenger, 2005). Behavioural and process studies, using underwater video, will likely employ statistical analysis; however, these relate to very non-mapping specific studies and are not considered here.

If a measure of reliance, “correctness” or “exactness” is to be placed on a seafloor classification, some form of statistical analysis providing significance is desirable. The application of statistics on data derived from seafloor video transects may fall into a number of categories, depending upon the required information that must be extracted from the footage – *the question in hand*. Statistical applications may commonly be applied under five circumstances, listed overleaf:
• **Descriptive** – to show the spread, range or variance of organisms over an area.
• **Distribution / goodness of fit** – to test if a distribution agrees with an expected distribution, or if it differs from an assumed norm.
• **Univariate hypothesis testing** – statistical, empirical testing of a theory.
• **Investigation of correlations** – between two or more counts or measures, biotic or abiotic, to look for associations.
• **Multivariate analysis** – primarily for comparison of assemblages from among a range of habitats.

It is critical that the video survey method and procedures are defined as a priori to the survey being undertaken and decided in unison with the planned analytical approach. This will ensure that the video footage, its processing into numeric details and the statistical applications are compatible; providing the relevant data to answer the defined questions and the anticipated information.

4.1 **Sampling**
Quantitative comparisons between either sub-sections of a video tow or among tows is dependent upon comparable coverage; i.e. either the time of the tow/sub-section and/or the distance [area] covered. As far as is possible, this should be standardised to ensure comparable coverage. Likewise, to ensure comparability, the same or very similar camera systems and setups should be used. Settings such as camera angle, height above seafloor (and hence area viewed), lighting, colour saturation, contrast and focus (fixed or auto) should be maintained constant.

Key to any statistical application is replication, or collection of a range of samples to facilitate comparisons. As an absolute minimum, descriptive statistics require three replicate sample counts, or in the case of video footage, counts from either 3 sub-components of a single video tow randomly selected, or 3 randomly placed video tows over a designated habitat type.

Preferably the number of replicate transects or independent sections of video that are processed should be as large as is practicable; this increases the accuracy of the calculated values of the sample population, which are themselves estimates of the true population. Five would be a good number for a stringent investigation. (Note: a count (n) of 50 is recognised as being statistically small (Elliott, 1977)).

4.2 **Descriptive statistics**
Descriptive statistics can be of use when explaining the structure and composition observed in a video transect. A comment can give the number mean of common urchins per m² and state a confidence interval around the stated mean; providing the reader with information on the range of urchin density above and below the mean within the surveyed area. Box plots may also be used to show the spread of the data, usually the minimum and maximum, median, 25th and 75th percentiles, outliers and in the case of Figure 7, the 95% confidence intervals about the median – the greyed area. Further detailed descriptive statistics can give more information of the

---

The concept of random sampling is an explicit, *a priori* in many statistical tests and as such, the selection of video tow sites, and/or selection of segments of footage from within a tow, needs consideration. This is discussed in further detail herein.
density and spread an organism in an area, for instance skewness and kurtosis give
details of the normality of a distribution and the agreement to a normal bell or
"Poisson" distribution.

Sample replication is required for the calculation of descriptive
statistics, these include: mean, median and mode averages,
minimum and maximum values, standard deviation and standard
error and % confidence intervals about the mean. They may go on
to include descriptors such as skewness and kurtosis – measures
indicating the frequency distribution of counts around the mean and
inter quartile range.

![Box plot example.](image)

**Figure 7.** Box plot example.

### 4.3 Distribution/ goodness of fit
The distribution of organisms may be expected in some areas of the seafloor to be
evenly or “normally” distributed, while across different areas, distributions may be
patchy or clumped. There are several tests and measures to identify significant
differences, and the extent of these differences within, between and among sample
areas. Examples include the G-test and \( \chi^2 \) (Chi-squared) test of observed and
expected frequencies. Both can be used to test for homogeneity, randomness,
association, independence and goodness of fit. These test the frequencies of counts
from samples (the observed) against a set of calculated frequencies – frequencies
that might be ‘expected’ according to likely numeric distributions.

### 4.4 Parametric and non-parametric statistics
Statistical hypothesis tests and investigations into relationships between data fall in to
2 classes: parametric and non-parametric. Parametric tests apply statistical
comparisons to the collected data; comparing means, while non-parametric depend
upon the ranking of data and comparison of the ranks, therefore comparing medians.
Parametric tests are recognised as being stronger, while they are also dependent
upon the frequency distribution of the data approaching normality or Gaussian.
There is no such *a-priori* assumption for the application of non-parametric tests, as
the tests are performed on the data’s ordered rank, not the data itself and therefore
any data skew, positive or negative has no effect on the rank order. However, it is
this transfer that results in the tests being performed on medians as opposed to
means as in the case of parametric tests, and they are classed as weaker than their
parametric counterparts.

### 4.5 Hypothesis testing
Hypothesis testing relies on the definition of a *Null Hypothesis* (\( H_0 \)) and an *Alternative
Hypothesis* (\( H_1 \)). The question that is posed should define the appropriate statistical
test and this will subsequently define the sampling regime that will be required to
collect the necessary data. Hypothesis test tend to compare averages (Table 1) and
as such, will require three or more samples – video transects or sections – to be
enumerated.

Note that Hypothesis tests may only disprove the null hypotheses, and while they
may not provide proof of the alternative hypothesis, they lend it reciprocal support.
4.6 Correlations
Measuring strengths of correlations and testing for statistical significance between variables (commonly between 2-organism counts or against environmental variables) can be made using parametric and non-parametric approaches. Commonly used examples include Product Moment Correlation and Spearman’s Rank Correlation respectively. Correlations can be positive (both variables increase together) or negative (as one variable increases the other decreases) and this is indicated by the calculated correlation coefficient ($r$), which will fall between -1 and +1 (indicating perfect negative and perfect positive correlations, respectively). As with hypothesis testing, parametric correlation tests are stronger than their non-parametric counterparts, however there are more stringent conditions for their application.

Table 1. Simple parametric and non-parametric test and their operation.

<table>
<thead>
<tr>
<th>Parametric hypothesis tests:</th>
<th>Non parametric hypothesis tests:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students t-test</td>
<td>Comparison of means of two small samples</td>
</tr>
<tr>
<td>z-test</td>
<td>Comparison of means of two large samples</td>
</tr>
<tr>
<td>Analysis of Variance (ANOVA)</td>
<td>Comparison of means of more than two samples</td>
</tr>
<tr>
<td>Two-way ANOVA</td>
<td>Comparison of means of more than two samples with the effects of 2 independent variables</td>
</tr>
</tbody>
</table>

| Mann-Whitney U-test                  | Comparison of medians of two samples     |
| Kruskal-Wallis test                  | Comparison of medians of more than two samples |

4.7 Multivariate analysis
Ecological systems are complex in nature and many biotic and abiotic variables interact stochastically producing distribution patterns. Multivariate statistical methods aim to investigate numeric patterns among data matrices – usually species counts in ecology – and cluster and separate like and dislike samples. Techniques fall into two categories: (a) (Table 2) hierarchical, dendrogram forming methods (Figure 8) and, (b) axis calculating, plot forming methods (Figure 9), which calculate values over a series of axes, each expressing a similarity gradients. The first axis provides the largest explanation of the data complexity and, subsequently providing reduced explanations of the data complexity, commonly Axis 1, 2 and 3 would then be plotted. Data are typically analysed with one of each technique, supporting identified sample clusters. Commonly paired techniques are TWINSPLAN with DECORANA, and Hierarchical cluster analysis with either PCA, or MDS. The decision at which level to stop sample division, or which axis to incorporate, i.e. assessing the importance of an analysis, can be made subjectively through working knowledge of the samples being analysed or through the use of statistical tools (McGraigal et al., 2000).

Table 2. Multivariate analysis techniques.

<table>
<thead>
<tr>
<th>Hierarchical techniques</th>
<th>X-Y plotting techniques</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hierarchical Cluster Analysis</td>
<td>Multi-Dimensional Scaling (MDS)</td>
</tr>
<tr>
<td>Two Way Indicator Species Analysis (TWINSPLAN)</td>
<td>Detrended Correspondence Analysis (DCA or DECORANA)</td>
</tr>
<tr>
<td></td>
<td>Principle Components Analysis (PCA)</td>
</tr>
<tr>
<td></td>
<td>Canonical Correspondence Analysis (CCA)</td>
</tr>
</tbody>
</table>
Figure 8. Example of DECORANA analysis of 20 samples grouping into seven classes (Axis 1 and 2).

Figure 9. Example of Hierarchical Cluster Analysis of 20 samples clustering into seven classes.

Analysis may focus on species, samples or both, showing the proximity of “species in sample space” – which species are common to the samples or “samples in species space” – showing which samples have comparable species assemblages. Results tend to be presented graphically and in table format. Graphs show the proximity of samples/species to one another with those shown closer together being most alike. Tabulated measures/scores give the calculated statistical values between samples and species.
Canonical Correspondence Analysis (CCA) and “BIOENV”, incorporate biotic (species count) and abiotic (environmental) data and assesses linkages among them. As with other techniques, the proximity of samples/species to one another in the plotted space indicates their similarity and the direction and strength of connections with the environmental data are then overlain.

These techniques are extremely useful in habitat – assemblage comparisons (Table 3), where video tows or samples have been collected over areas of seafloor that are believed to constitute similar and dissimilar “habitats”. Assemblage data (counts of organisms) from video footage or samples can be processed by multivariate analysis to investigate similarities, with the expectation that like (similar) habitats will support similar biotic communities.

The next logical step is to statistically test the separation among multivariate clusters. The technique ANOSIM, which is defined as a permutation-based hypothesis test, is analogous to the univariate analysis of variance (ANOVA). This technique tests for differences among groups of (multivariate) samples, be they from different times, locations and/or experimental treatments (Clarke and Warwick, 1994).

**Table 3.** Advantages of multivariate statistical techniques for ecological data (after McGarigal et al., 2000).

- Reflect more accurately the true multidimensional, multivariate nature of natural ecological systems.
- Provide a way of handling large data sets with large numbers of variables by summarizing the redundancy.
- Provide rules for combining variables in an “optimal” way.
- Provide a solution to a kind of multiple comparison problems by controlling the experiment wise error rate.
- Provide for *post-hoc* comparisons, which explore the statistical significance of various possible explanations of the overall statistical significance of the relationship between independent and dependant variables.
- Provide a means of detecting and quantifying truly multivariate patterns that arise out of the correlational structure of the variable set.
- Provide a means of exploring complex data sets for patterns and relationships from which hypotheses can be generated and subsequently tested experimentally.

Another branch of multivariate analyses are those employed in tailored computer processing applications for habitat alignment or definition. An example of this is the Marine Habitat Matching Programme (MESH, 2006a). This application automates the classification of either taxonomic listings and abundances of epibenthos or physical habitat descriptors (nine are included) into standard habitats (or biotopes), defined as a set description files listing the taxa, their abundances and the physical variables found in each. Recognising the implicit uncertainties in assigning habitats/biotopes in this way, the five most likely habitat resulting matches are given by the programme with their associated indicator values (Table 4). The user can then apply empirical knowledge in selecting from the resulting list.
In practice, classifications are performed independently on biological or physical data, although these can be run and displayed simultaneously. For physical data, the Biotope Matching Programme relies on Principle Components Analysis and Euclidian distances to ordinate the standards. For biological data, Attractor-Repulsor Multidimensional Ordination (ARMO) or “Gravity clustering” is used (MESH, 2006a).

In the Marine Biotope Matching Programme, absolute count values are used for infaunal counts, while epibionts are treated as semi-quantitative abundance based on the SACFOR scale, where data are categorised into six categories: Super abundant (>80%); Abundant (79-40%); Common (39-20%); Frequent (19-10%); Occasional (9-5%) and; Rare (1-5%) (see http://www.jncc.gov.uk/page-2684 for details of application).

This application is of value in validating the results of grab samples against standards and may be applicable to species count data derived from video transect footage. Testing and application will presently be needed to confirm this.

**Table 4.** Indicator values calculated by the Marine Biotope Matching Programme.

<table>
<thead>
<tr>
<th>Biological habitat/ biotope matching similarity scores:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MaxDist.</strong></td>
<td>The maximum distance from the samples allocated position in multidimensional space to the furthest least similar standard sample. This is a measure, in the multidimensional environment in which the calculation was performed, of the similarity and dissimilarity of the sample to the tabulated standard.</td>
</tr>
<tr>
<td><strong>No Iter.</strong></td>
<td>The number of iterations until a solution was found.</td>
</tr>
<tr>
<td><strong>Dist.</strong></td>
<td>The relative distance from the sample to a particular habitat standard.</td>
</tr>
<tr>
<td><strong>In Com.</strong></td>
<td>The proportion of taxa in common between the sample and the standard.</td>
</tr>
<tr>
<td><strong>Not In Com.</strong></td>
<td>The number of taxa not in common (note the difference between the proportional measure in common and the count of taxa in not in common).</td>
</tr>
<tr>
<td><strong>Pearson.</strong></td>
<td>The Pearson product moment correlation coefficient between the standard and the sample.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Physical habitat/ biotope matching similarity scores:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MaxDist.</strong></td>
<td>The maximum distance from the samples allocated position in multidimensional space to the furthest least similar standard sample. This is a measure, in the multidimensional environment in which the calculation was performed, of the similarity and dissimilarity of the sample to the tabulated standard.</td>
</tr>
<tr>
<td><strong>Dist.</strong></td>
<td>The relative distance from the sample to a particular habitat standard.</td>
</tr>
</tbody>
</table>
5 Cost-benefit analysis of varying qualitative and quantitative approaches

J. White

The time and resources necessary to collect video footage adequate for statistical habitat classification will not be notably different from that necessary for footage collected for subjective analysis. Although slightly more planning will be necessary for collecting footage intended for statistical analysis; defining objectives and hypotheses and all deployments will need to be comparable, the vessel, equipment and personnel costs will however, not differ markedly. Analysis time may however differ, as for statistical analysis each transect will require detailed analysis and enumeration, requiring at least 2 viewings. The analysis will then require data formatting, application of tests and deference of resulting test statistics.

The resulting conclusions of statistical analysis will be of much greater value than the purely subjective, as significance values and confidence indices will be derived, in accordance with the devised test hypotheses and objectives, informing the investigation of the differences among defined habitats and the location of habitat borders.

6 Discontinuous habitat coverage – sampling regimes

J. White and A. Mitchell

In a targeted habitat mapping ground truthing campaign, video tows are usually made within the intrinsic identified acoustic facies. For comparative purposes, it is advisable to make replicate tows over facies that are believed to be the same – to ensure consistency in classification. Additionally or alternatively and utilising either a classification system or statistical methods, sample replication may be created by selection of sub-sections of video tows, again for comparison over the length of a tow and among tows.

Care needs to be taken if sub-sections of footage are to be separated from single video tows into separate samples, as sample independence is an essential requirement of most statistical tests and there is potential for spatial autocorrelation (Hurlbert, 1984 - Pseudoreplication and the design of Ecological field experiments). Sections of the tow to be separated, must to be chosen randomly to apportion sample independence, while inherent uncontrolled camera drift, regardless of vessel steering, may be including as a random element to sampling. Re-sampling techniques such as bootstrapping and jackknifing may be of value in such situations to provide more robust estimates from smaller independent samples.

Towing across the boundaries between two or more acoustic facies may be a valid approach utilised to determine if different acoustic signatures constitute differences in physical structure and biological composition. Where tows over boundaries are made, the video footage should be separated into sections for its analysis. Count data or categorisation of video segments should be portioned into the acoustically classified areas.
Comparison of video footage can be made using statistical testing if counts of organisms are made, or classification follows a categorization system such as EUNIS. Typically three questions will be of interest:

- what is the physical structure and/or biological composition of an area and can it be classified/described as a habitat "unit", either user-defined or in line with a recognised classification system;
- are other defined habitat units in the area/ sample set the same;
- are other defined habitat units in the area/ sample set different.

To investigate a series of acoustic facies, Preston et al. (2001) identify that "a small number of samples from each class" are necessary to define "the geophysical type of the entire class". Concerning video or grab samples, replicate sampling of each facies is advisable and critical if a statistical assessment, with a supporting significance value is sought. As a minimum, 3 but preferably 5 "samples" from each facies, with a sample defined as either a full video tow or as randomly selected sections from within a video tow over a single acoustic facies, should be collected. Replication is advisable to ensure that a true representation of the facies is achieved, as one "view" alone could provide an un-characteristic description of the facies. For statistical investigation replication is essential, as most tests compare means or medians.

Figure 10 shows a schematic representation of acoustic classification of 4 seafloor facies, and Table 5 shows a series of different possible video sampling programmes and the number of video tows associated with each. Ideally each area should be investigated with replicate samples, giving 3 or 5 samples from each facies, A to D; resulting in 45 and 27 samples respectively (Scenarios I and II). Scenario III indicates a single video tow made through examples of each facies A to D. This scenario would give footage, permitting classification, of the 4 acoustic classes to a system such as EUNIS. By sub sampling each of the tows, it could be determined if different sections of the tows were different to one another. However, this would not ensure that the different regions of each assumed facies type were the comparable. A development on from this, scenario IV, looks at collecting a video traverse across each area in each class and subsequently sub dividing video tows into 3 separate samples.

Scenario V presents a situation of 3 tows made across the boundaries between each of the classes; providing 3 matched comparisons for each boundary and a total of 9 sections of footage over each facies (by dividing each tow into the coverage of it’s two component facies). Scenario VI illustrates one cross-facies video tow being made for each possible boundary cross, which provides 3 sets of footage over each facies. Scenario VII covers collecting video tow footage across junctures between each example of each facies (for example there are three intersections between facies C and D: C1 - D1; C1 - D2 and; C2 - D2). This scenario provides 16 video tows, each covering 2 facies, giving 6 sections over facies A, 9 over B; 8 over C and 9 over D.
Table 5. Sampling regime scenarios.

<table>
<thead>
<tr>
<th>Facies</th>
<th>Number of samples/areas/facies</th>
<th>Number of Samples/ Sampling Scenario</th>
<th>Across site samples</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>I</td>
<td>II</td>
<td>III</td>
</tr>
<tr>
<td>A</td>
<td>10</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>B</td>
<td>15</td>
<td>9</td>
<td>1</td>
</tr>
<tr>
<td>C</td>
<td>10</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>D</td>
<td>10</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Cross Facies</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A - B</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A - C</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>A - D</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B - C</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>B - D</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>C - D</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Sum of tows: 45 27 4 9 18 6 16

Sum of video sections: 45 27 4 27 36 12 32

Any one or a combination of these sampling regimes, may be appropriate, dependent upon exactly what is to be determined. For instance a purely subjective analysis (provided through scenario III) would require the least time, both for collection and processing, while scenario I will provide the most robust data for classification of each area. Scenarios V and VI present a good compromise; providing opportunity to observe changes across the areas and data for statistical testing among the four classes, and in the case of scenario VI, within each individual area.

7 Groundtruthing video survey based upon Acoustic survey

Presently a standard approach to habitat mapping involves an initial acoustic survey of the seafloor, from which bathymetry and backscatter are mapped. The backscatter facies can then be used to advise the minimum ground-truthing sampling requirements; the use of optimum allocation analysis and the use of acoustic variability/backscatter as a surrogate for habitat heterogeneity.

The length of video tows, in terms of time and distance, will also require consideration during surveying. It is imperative that enough footage is collected to provide valid robust sets of data describing the targeted facies. If a facies boundary is crossed, then sufficient footage should be recorded within each facies. Care must be taken to plan the tows in such a way so valuable survey time is wasted, as excess footage will not necessarily be processed or add to the analysis.

The replication in video tows, or selection of sub-sections from a tow to provide replicate samples, is necessary to achieve an indication of certainty that a benthic community has been sufficiently characterised within an acoustic facies (this being reliant on the calculation of means, variances and standard deviations, for which replicate samples are necessary).
A required minimum of five replicate video tows/drops per distinct ground-type has been recommended. During time-constrained operational activities, three replicates may be acceptable, however, this will be at the expense of the degree of confidence that may be placed in the characterisation, particularly in the case of heterogeneous grounds, while in homogeneous grounds five replicates may be excessive.

The degree of replication necessary to obtain an acceptable level of confidence is dependent on the degree of heterogeneity within a facies, and this may differ significantly between facies. The spatial extent of facies should also be taken into consideration. Both of these factors are likely to affect the likelihood of the facies’ biotope composition being adequately sampled for classification.

Optimal Allocation Analysis (OAA – see separate paper) provides a method that allows ground-type heterogeneity and ground-type area to dictate the number of samples necessary from each facies to achieve a certain degree of precision in the resulting biotope classification. This method makes the assumption that remotely sensed or acoustically derived variables may be used as proxies to indicate the level of heterogeneity within a facies. This in turn is assumed to be indicative of the heterogeneity of the ground-type and biological community, both contributing components of classification of a biotope.

Acoustically derived variables could include slope angles, aspect, rugosity and/or backscatter data. Once a particular study area has been classified into a series of facies based solely upon these proxies, then the mean and standard deviation for each remotely-sensed variable for each ground-type is calculated (see OAA paper for details of how to undertake this task on large datasets using GIS tools). The spatial area of each ground-type is also calculated. Coefficients of variance are calculated (now available in an Excel Macro) for each facies dataset to determine the recommended number of ground truthing samples.

There is considerable freedom in choosing which remotely sensed variables are incorporated into the analysis, or weighting of different variables based upon expert judgement and/or local knowledge. It is recommended that the facies combined areal extent is routinely used to help drive the sampling effort. The decision must be made of what degree of precision is desired and this can be entered into the analysis as a coefficient of variance; with the higher degree of precision demanding more sampling. Alternatively, where budget or time dictates the maximum number of samples possible for a survey area, OAA may be used to drive the sampling design.

The recommended sampling output from OAA is in area units (e.g. m²) per ground-type. It is then up to the surveyor to decide how to undertake such sampling, with respect to a series of short video drops or fewer long video tows per facies and where these should be located within the facies. Where statistical analysis of results are required, sample independence must be considered (see above), which would favour a higher number of short video drops. In most cases, facies are split into a number of patches throughout the survey area. OAA recommended sampling is for the total ground-type area and therefore the surveyor must choose how to distribute the sampling effort between patches of the same ground-type (see below Section 1.5).
Where a broad physical habitat classification is required, such a level of analysis prior to ground-truthing is unnecessary, but the OAA approach is suitable where classification to EUNIS Levels 4/5 or higher (i.e. incorporation of significant assessment of benthic biota) is desired.

8 Random vs. structured sampling patterns within a ground-type, and considerations of sample independence

Deciding between a random or structured sampling regime can be philosophically complex, though the issues can be summarised quite simply. Most statistical tests hold implicit assumptions, which if broken can in theory render results inappropriate. One such assumption is that samples are collected randomly from the potential sample population – translating this to seafloor video sampling (and also applicable to grab sampling) then samples need to be collected from random locations within the habitat. This raises the question of knowing the size and shape of the seafloor habitat – very possibly exactly what the sampling programme is trying to determine. Other issues that need to be addressed include designing an optimal sampling regime within limited survey time and obtaining information of organism distribution over an area.

Several solutions currently exist to these issues. One solution is to undertake an acoustic survey over the area prior to groundtruthing (this can be weeks or hours before) and assume initially that acoustically designated facies relate to biological habitats. This assumption can then from the basis of a sampling regime with each facies representing a habitat and for sampling, the potential sample population, within which random sample locations are then defined. This will provide random samples within a presumed habitat.

Unless there is plenty of time available for sampling and the area is small, random sampling may lead to a distinctly uneven sampling programme across an area. This may result in marked differences in the sample contents, particularly if there is a grading of habitat from one side of the area to the other. Formally spaced samples, with more even distribution would account for such gradation (Figure 11).

The decision to adopt a random or structured sampling structure is reliant upon the intended analytical processing. If hypothesis testing is required, random sampling is expected, however if the investigation aims to determine changes in community with distance then a structured sampling programme will be more appropriate.

![Random and Grid Sample Designs](image)

**Figure 11.** Random (left) and grid structure (right) sample designs. Shading representing a gradual shift in habitat community.
9 Random vs. structured sampling patterns in the field

9.1 Introduction
Random sampling generally ensures that all individuals within a population have an equal chance of being sampled. This approach is widely acknowledged to be the most likely to generate reliable estimates of community parameters with sufficient sampling. Random sampling across a wide marine area can rarely be justified however, on the bases of time and cost. An approach of stratified-random sampling is often adopted, which subdivides the survey area into a number of homogeneous regions, each of which is then randomly sampled.

Acoustic techniques (AGDS, mulitbeam, sidescan sonar and interferometry) are commonly used to identify ‘ground types’ across the survey area, allowing a stratified-random sampling pattern to be designed across them. Replicated systematic sampling is often applied as it avoids sample bias better than haphazard single sampling and has proven easier to apply in the field than random sampling. Systematic sampling is not however, equivalent to random sampling, for if there is periodic ordering within the chosen samples, systematic sampling may have a larger error than a random sample. The use of dynamic GIS systems for survey planning and data capture in the field, now allow far greater flexibility for re-design of stratified-random sampling strategies, at short notice with near instantaneous results. The result being that for practical purposes, sampling methods other than stratified-random sampling are rarely employed.

Benthic habitats may show spatial associations over different scales relative to the overall scale of the survey. These habitats and their scales require investigation to ensure that the true nature of the ground is captured at the relevant scale for the mapping being undertaking, and ultimately, the application for which the mapping is designed.

9.2 Spatial and temporal analysis of video sample data
Investigation of spatial associations of benthic habitats over different scales, relative to the overall scale of surveys, has been undertaken utilising examples from surveys conducted between 1996 and 2006. Two specific examples are presented in the following sections:

- Example 2: Sampling highly heterogeneous areas, Loch Maddy (page 42).

9.3 Spatial association of samples
Fine scale association (where two sample lying close to each other are more likely to be similar than more distant samples) underpin replicate (at one point in time) and repeat sampling (samples taken in same place at two or more points in time). If the benthic habitats are very heterogeneous, then there will be a high degree of variability between samples that are very close to each other (as compared with the variability between all samples).
This may have a number of different impacts on a survey:

- Descriptions of spatial distributions based on point samples will need to be structured to show the variability that might be expected;
- Apparent temporal changes may simply reflect heterogeneity, and;
- Correlations between sample data and other data (such as acoustic information) may be compromised owing to a combination of resolution and positional inaccuracies.

Fine scale heterogeneity is often termed ‘noise’ when at or below the limits of resolution of a survey. The scale of the detected and defined habitats will implicitly be a factor of the scales datable and investigated by the mapping and sampling techniques used, which must be chosen relative to the needs of the survey outputs. The sizes and distributions of habitats will interact over different scales. Within a survey, there may well be broadscale trends above the nature of fine scale heterogeneity. This fine scale heterogeneity, while representing an essential habitat unit of a fine scale survey, may well be exhibited as “noise” over statistical trends in habitat metrics that appear at a broadscale. Indeed habitat patches themselves may exhibit normal, random or patchy distributions, and conversely, a habitat with mappable patches may show no broad scale trend in the distribution of its patches.

For these reasons, it is important to examine the collected point data and establish the level and scale of spatial variation in order to assess the ‘noise’, patchiness and broadscale trends (Foster-Smith, et al., 2001). This should assist in determining whether the sampling strategy employed has been effective at capturing the real nature of the ground, rather than merely inconsistently capturing heterogeneity over a very small scale.

Envision Mapping, Ltd. has conducted analysis based on previous surveys to assess the rigour of the stratified-random sampling methods employed and identify whether or not there were any overall spatial association in the data. In order to test this question all the ground-truth (GT) data were analysed in terms of the lag distances between samples over time versus the percentage of similarity. In this way, temporal associations between conventional grab sample data can be used to help identify the heterogeneity of the ground type and sampling strategies for drop down video can be more easily assessed.
9.4 Example 1: The use of video sample data for specific species detection, *Sabellaria spinulosa*

A series of surveys were undertaken in the Wash for the specific purpose of developing techniques for the detection, mapping and monitoring of the biogenic reef building Ross Worm, *Sabellaria spinulosa*, (Box 1) to support the UK’s Biodiversity Action Plan.

**Box 1. *Sabellaria spinulosa* Surveys**

The ‘ross worm’, *Sabellaria spinulosa* (Leuckart 1849), is a sedentary, epifaunal polychaete that builds rigid tubes from sand or shell fragments. It is a suspension feeder that is generally found individually but can be gregarious in favourable conditions, and colonies consisting of fused sand-tubes may form thin crusts or extensive reefs. The reefs are solid but fragile structures, which can be up to several metres across and raised above the sea bed by up to 30cm.

Significantly, the reefs can persist for many years and as such, they provide a biogenic habitat that allows many other associated species, including epibenthos and crevice fauna, to become established. As such, the fauna is distinct from other biotopes and species can become established in predominantly sedimentary areas where they would not otherwise be found. *S. spinulosa* has therefore been identified as a priority habitat under the Biodiversity Action Plan (BAP), the UK's initiative to maintain and enhance biodiversity.

There are only a few areas of known *Sabellaria spinulosa* reef in UK waters (and very few in other European waters). The primary site used for testing was an aggregate extraction site, known as site 107, off the Lincolnshire coast. The reefs are also present in the surrounding areas of the Wash. Selected areas within this site were chosen on the basis of video tows that showed there to be well developed *Sabellaria* reef, areas of non-reef sand and other sand wave features, which were ideal for the purposes of the study.

**Survey design**

The series of surveys undertaken had different objectives that evolved from one year to the next. Thus, the scale of survey, techniques used and strategy also changed. The data were often not as complete as hoped for owing to poor weather and underwater visibility. Figure 12 shows the area of survey and features of the survey design, Table 6 summarises the survey objectives.

Video and grab samples did not always correspond (Table 7). Despite video having the obvious advantage of direct observation of reef structure, locations with quite dense *Sabellaria* were often not observed as *Sabellaria* biotopes on the video. It is likely that tubes can be obscured by overgrowths of epifauna. Conversely, reef structures sometimes were not confirmed by grab sampling. In these cases it is possible that the grab may have missed *Sabellaria* if the reefs were patchy.
**Figure 12.** The AGDS track data showing the location of transects and sample boxes. The sample boxes are in their final positions. Note that sample 7 was chosen later in the survey to investigate the boundary conditions at the edge of area 107.

**Table 6.** Summary of Envision/SeaMap surveys in the Wash between 1996 and 2004.

<table>
<thead>
<tr>
<th>Year</th>
<th>Acoustic survey</th>
<th>Sampling</th>
<th>Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>1996-99</td>
<td>Broadscale mapping:</td>
<td>Stratified sampling: grab and video</td>
<td>Large area of the Wash and Lincolnshire coast</td>
</tr>
<tr>
<td></td>
<td>AGDS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>Detection: AGDS/Sidescan</td>
<td>Replicate sampling: grab and video</td>
<td>Long Sands and 107</td>
</tr>
<tr>
<td>2001</td>
<td>Spatial patterns: AGDS/Sidescan</td>
<td>Random sampling: grab and video</td>
<td>7.1 km quadrats along transect from inner Wash to 107</td>
</tr>
<tr>
<td>2003</td>
<td>–</td>
<td>Repeat random sampling: grab and video</td>
<td>Quadrats 1 and 4 (above)</td>
</tr>
<tr>
<td>2004</td>
<td>Spatial patterns: AGDS/Swath</td>
<td>Repeat random sampling: video</td>
<td>Quadrats 1 and 4</td>
</tr>
</tbody>
</table>

**Table 7.** Correspondence between information recorded from video and the data from infaunal analysis. Green cells highlight samples where correspondence was acceptable; the red cells where there was a mismatch.

<table>
<thead>
<tr>
<th>Grab Infaunal class</th>
<th>Video life form</th>
<th>Sabellaria</th>
<th>Non-Sabellaria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense Sabellaria</td>
<td>6</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>Sparse Sabellaria and epifauna</td>
<td>3</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Moderate Sabellaria</td>
<td>4</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Anemones and epifauna</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Sparse epifauna</td>
<td>4</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Dense epifauna</td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Barren</td>
<td>3</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Ophiura and epifauna</td>
<td>0</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>
Clearly, mismatching results indicate issues with these techniques. Video has the advantage of enabling large coverage, whilst grabs provide specimens which can be enumerated for quantitative measurement of abundance and speciated under laboratory conditions. Video however, may miss poorly developed reef or obscured reef, whilst grabs will give data with, potentially, a high level of variability (sample variance) that is dependant upon heterogeneity.

**Visual analysis**
The high degree of spatial heterogeneity encountered over the survey site and within each survey sample box (Figure 13) can be analysed by determining the pair-wise similarity/dissimilarity over increasing separation distance (termed ‘lag’). If the area were homogeneous, then similarity between samples close to each other would be high. If, on the other hand, the area were heterogeneous, the similarity would be low. Figure 14 illustrates the relationship between similarity and lag and at the closest spacing (within 200m), the similarity was relatively low (0.2) (the expected frequency for randomly distributed samples being 0.11).

Intriguingly, similarity frequency showed a second peak at a lag of 1000m. This coincided with the distance across the deeps and may represent a repeated pattern in this direction. Clearly however, samples indicated a very patchy biotope distribution, making accurate and detailed mapping difficult. The problem was compounded as various biotopes were not clearly distinct in video footage or samples. Many of the same component habitat features and conspicuous species were apparent in each, but in varying proportions.

**Figure 13.** All field samples from the Long Sands site (sample Box 5,) colour coded to biotope.

**Figure 14.** The frequency with which samples are of similar biotopes with increasing separation distance (lag). The red horizontal line indicates the frequency expected by chance.
Implications for survey strategies
Choosing the scale for sampling and the area for survey for the Wash and its environs must be matched to the priority questions that need to be addressed for monitoring the status of the reefs and related Sabellaria biotopes (as well as the techniques available and survey cost). Sample example options are given in Table 8 with reference to Figure 15.

Table 8. Examples of options for monitoring the status of reefs in the Wash (reference to scale related in Figure 15).

<table>
<thead>
<tr>
<th>Scale</th>
<th>Techniques</th>
<th>Positioning precision</th>
<th>Cost/effort</th>
<th>Issues addressed</th>
<th>Issues not addressed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quadrat (25m²)</td>
<td>Continuous coverage: Videography, photography and diver sampling</td>
<td>Very precise: DGPS and acoustic beacons</td>
<td>High for sample quadrat; prohibitive for large survey area</td>
<td>Patch dynamics of reef; sequence of reef construction and decline</td>
<td>Significance of change hard to assess in broader context</td>
</tr>
<tr>
<td>Box (500m²)</td>
<td>AGDS; random sampling within box: videography, grab samples, diver collected samples</td>
<td>GPS (assuming no selective availability)</td>
<td>Videography low; grab low to moderate depending on infaunal analysis</td>
<td>Statistics of box used to assess change</td>
<td>Hard to extrapolate change to whole area; little information on patch dynamics</td>
</tr>
<tr>
<td>Box (500m²)</td>
<td>As above plus acoustic imaging</td>
<td>As above</td>
<td>As above; Imaging unknown</td>
<td>As above plus boundary changes within box associated with patch dynamics</td>
<td>Hard to extrapolate change to whole area</td>
</tr>
<tr>
<td>Whole area</td>
<td>AGDS survey plus selected sampling using videography and grabs</td>
<td>As above</td>
<td>High to achieve adequate coverage and sample intensity for repeat survey; Moderate if indicative only</td>
<td>Broad scale changes mapped; comprehensive statistic for whole area</td>
<td>Even intensive survey is imprecise for measurement of change; If indicative then statistics unreliable</td>
</tr>
<tr>
<td>Box and belt transect</td>
<td>AGDS for belt; as option 2 and 3 for boxes</td>
<td>As above</td>
<td>Moderate to high depending on number of boxes and sampling</td>
<td>Broad scale changes along preselected gradient</td>
<td>Changes outside transect not assessed, changes between samples extrapolated and therefore imprecise (indicative only)</td>
</tr>
</tbody>
</table>
Random sampling within monitoring areas that follow a broad environmental gradient
One of the issues raised in this survey series was that of random sampling within monitoring areas that follow a broad environmental gradient. It is clear that limited sampling in an area is insufficient to be able to sample the full range of biotopes (e.g., *Sabellaria* biotopes were not sampled at the Long Sands site in months with more limited samples available). A larger number of samples would allow a statistical assessment to be made of the *Sabellaria* population within a sampling area and the spatial heterogeneity (dispersion) of the population. These sampling areas might be about 500m² and arranged following the northern flank of the Lynn Deeps/Scott Patch feature. The analysis would produce summary statistics for each site that could be used to detect broad scale spatial and temporal trends.

Video remains one of the recommended field sampling techniques to complement grab samples. Despite problems of poor visibility, video can be rapidly deployed and many records can be collected in a short time. Experimentation with downward-facing digital video in a fixed frame and use of freshwater lens (Section 3 Camera use in turbid waters) may reduce the problems of poor visibility that affects forward-facing videography.

Pattern and Patches
The distinction between pattern and patchiness depends on the scale of observation used: broad scale survey (low resolution with sparse sample coverage) may render an area as having a very mixed patchy habitat structure with indiscernible edges to the habitats, whilst a fine scale survey (high resolution with a dense sample coverage) may show the definable habitat patches and pattern. For mapping, this will be determined by the combined errors from the sample area and positional inaccuracies of the acoustic image and the ground truth observation. If two locations were not spatially distinguishable within the in the survey area, the information from
the two points would have to be integrated into a combined description. If the benthos at these two points differed, then descriptive statistic would need to measure the level of variability. This variability may be described as a measure of patchiness. In other words, patchiness is a measure of the variability of the data at and beyond the limits of spatial resolution of the survey. This inherent variability is termed the ‘nugget’ in variography.

**Survey design for variability**
A standard approach to assess the level of this variability and hence mitigate against fine scale heterogeneity is to take and assess differences among a small number of replicate grabs taken at the same location, but allowing for drift and spatial imprecision to space the samples. In 2000 five sites (3 at area 107 and 2 at Longsand) were sampled three times and the positions logged as accurately as possible (dGPS close to point of deployment of grab, but with no control over drift of the grab). The number of Sabellaria in each grab were used to calculate similarity between pairs of grabs which were then plotted against lag distance (distance between the pairs) (Figure 16). The variability between samples that were close together was extremely high with no obvious decrease in similarity as lag distance increased.

Over short distances, closely spaced samples were no more similar to each other than more distant samples. This would indicate that there were no very local patterns within the region of 80m (± the estimated drift error). The local mean value of the samples was the best estimate for any point within the area encompassed by the samples.

![Figure 16](image_url)

*Figure 16.* Similarity between pairs of samples (based on Sabellaria numbers) plotted against the distance between the pairs (lag distance).

This strategy has two main drawbacks: (1) three samples are too few to estimate variability or a mean that can be used as a yardstick for measuring change, and (2) the area encompassed by the samples was small (100m) and any apparent change measured by repeating the sample might reflect patchiness at a slightly broader scale rather than any real change.
The strategy for the 2001 survey was based on random samples within a large quadrat in an attempt to overcome these problems. The survey strategy was, in outline:

- Highlight areas likely to support *Sabellaria spinulosa* identified from previous broadscale surveys.
- Select seven 1 km$^2$ ‘quadrats’ placed at intervals along a transect from the inner Wash, along Long Sands/Lynn Deeps to further offshore outside the cSAC boundary (the Scott Patch area and area 107).
- Random sample within the 1 km$^2$ quadrats.
- Use remote sensing techniques to detect spatial structures at a fine scale within the super-quadrats.
- Re-survey in 2004 to assess change.

The super-quadrats had sides of 1 km. Ten grab samples were collected from randomly selected stations (but accurately located to within 50 m) within the boxes and these were assessed visually for reef development, sediment granulometry estimation and then the infauna were extracted and preserved for later identification. Each of these grab sample sites was also sampled with a drop down video which could not only assess the physical scale of reef development but also be used to gauge the patchiness of the biotopes at a broader scale than the grab sample. Selection of sample locations is explained in Section 0 Random sampling.

**Assessing spatial variation for video sample area selection, using grab samples**

Samples with counts (numbers of *Sabellaria spinulosa*) can be subjected to another graphic demonstration of spatial correlation in which variance between pairs of samples is plotted over increasing lag distance (Burroughs and McDonnell, 1998). In the following analysis, the variances in the similarity between pairs of samples over lag distances have been calculated for each of the Boxes separately. The pair-wise similarities were placed into bins of increasing lag distances. The exact bin ranges varied between Boxes depending upon the spread of pair-wise lag distances and bins with less than 4 pairs were discarded. Since variance depends on the absolute numbers, the variances for each lag bin were standardised by dividing by the total variance within each box, to enable the plots for the Boxes to be more easily compared. The variance/lag graph for each Box has been plotted separately in Figure 17. Also included is the variogram for the pooled data, shown as the thick black line. The larger data set has meant that a larger number of lag ranges were possible for this calculation and a meaningful, smooth graph possible.
The variances were themselves very variable between successive lag distances, but few graphs showed any clear sign of increasing variance with increasing lag distance (which would be expected if samples close to each other were more similar in numbers of *Sabellaria* than those further apart). There may however, be some indication of spatial correlation in Boxes 1 and 7. There is no general tendency for samples to show spatial correlation.

**Indices of dispersion**

The similarity of the *Sabellaria* numbers in the 10 sample locations within a Box together with their position can be used to measure dispersion using indices such as “Moran’s I”. The basis of such indices is to create two site/site matrices of (1) separation (lag) distance and (2) similarity and then calculate the cross-product of corresponding cells in the matrices. The value of the Moran’s index approaches -1 when the sites over a given lag distance are more dissimilar than might be expected (negatively correlated) and +1 when they are more similar (positively correlated).

The indices can be calculated for different lag distances and this gives an indication of the way dispersion/aggregation changes with increasing distance separating the sites. Moran’s indices were calculated for increments in the lag distance of 150 m up to just over 1 km and Figure 18 summarises the pattern for all seven Boxes.

Moran’s I tended towards a slightly negative value at the larger lag distances and at small lags (where the significance of the indices is low because of the smaller number of pairs in the calculation), was very variable. Two sites (Boxes 2 and 6) showed a gradual decrease in Moran’s I which might indicate some positive correlation at small lags. The highest values were not large (approximately 0.25) and it is doubtful if the trend is interpretable.

If all data are pooled, then there is only a weak trend in spatial association (Figure 19). There was no general tendency for samples to show spatial correlation over the quadrat and this supports the working model of the quadrat as being uniformly
heterogeneous. That is to say, the randomly selected samples are likely to be statistically representative of the quadrat as a whole.

**Figure 18.** Moran’s I calculated for each of the 7 Boxes for lag distances ranging from 150m to 1050m.

**Figure 19.** Median and mean Moran’s I for the 7 Boxes for lag distances ranging from 150m to 1050m.

**Sampling summary**

The survey design was based on stratified and nested sampling of selected sites based on broad scale predictive maps produced by AGDS and more recent surveys. It is important to note that the purpose of the classification of the remote data was to interpret using supervised classification techniques and not to define the acoustic characteristics of biotope ground. This is perfectly acceptable if the area is stable and repeat sampling can return to target areas. If long term stability cannot be assumed however, and stratified sampling for target biotopes is required, then it is important to be able to predict the sort of ground where they are likely to be found. In other words, AGDS is used as a real-time prospecting tool to identify particular ground types.

Thus, the strategy for the 2001 survey consisted of the following stages:
1. Highlight areas likely to support *Sabellaria spinulosa* identified from previous broadscale surveys. The sites selected for the 2001 survey were to be placed at intervals along a transect from the inner Wash, along Long Sands/ Lynn Deeps to further offshore outside the cSAC boundary (the Scott Patch area and area 107). This disposition of the sites was designed to detect any broad offshore/onshore trends.

2. Resurvey these areas using RoxAnn in real-time to refine the selection and position of the box sampling areas (or ‘super-quadrats’).

3. Having stratified the sampling, to randomly sample within the super-quadrats.

Use remote sensing techniques to detect spatial structures at a fine scale within the super-quadrats.

The super-quadrats had sides of 1km (original design 250m – see discussion under 0 Methods). Ten grab samples were collected from randomly selected stations (but accurately located to within 50m) within the boxes and these were assessed visually for reef development, sediment granulometry estimation and then the infauna were extracted and preserved for later identification. Each of these grab sample sites were also sampled with a drop down video which not only could assess the physical scale of reef development but also be used to gauge the patchiness of the biotopes at a broader scale than the grab sample.

**Stratification: selection of Box sites**

Six boxes were planned, but in the event 7 were sampled. This was because the absence of well developed reef in the area of Box 1 where it was previously abundant required further investigation of the boundary conditions of the licensed sand extraction area 107.

The original size for the boxes was planned to be 250m. On further consideration however, this was not considered to be sufficiently large regarding the spatial imprecision of the grab sampling. Bear in mind that the samples were to be separated from one another by a known distance, with a margin of error for spatial imprecision. It was estimated that the grab sample could be as much as 50m out from recorded position (mostly owing to drift of boat and grab relative to DGPS position as recorded).

The map used to select the approximate location of the super-quadrats is shown in Figure 20. This was obtained using AGDS with video ground truthing in a previous broadscale survey. The boxes were selected on the basis of maximum probability of the occurrence of *Sabellaria* at high densities.
Figure 20. Sampling boxes superimposed on the predicted infaunal and epifaunal biota. The former is shown by the background colour and the latter by the hatch pattern.

Random sampling
The locations were selected by placing a grid of numbered 25 m$^2$ squares over the super-quadrat and randomly selecting ten. Some extra locations were selected in case it proved impossible to grab at one of the ten selected locations (e.g., owing to static fishing gear) and in such cases a duplicate grid location was selected at random. The final selection of locations is shown in Figure 21.
Box 1

Box 2

Box 3

Box 4

Box 5

Box 6

Box 7

Figure 21. Position of grab and video samples for each box.

Video
The direct observations were made with a digital video system and the tows were also recorded simultaneously on the surface unit in Hi8 format. After grab samples were collected, the sample stations were re-visited and the video deployed so that the boat would drift (as near as could be anticipated) over the grab station. The tows lasted for no less than 2 minutes and a maximum of 3 minutes. These videos were viewed and assessed for biotope features, reef development and patchiness.

Results: Grab and video samples
Numerous analyses have been carried out on the data and the purpose and procedures of the various stages require some explanation. Table 9 summarises the strategy for the analysis of grab and video sample data.
<table>
<thead>
<tr>
<th>Purpose</th>
<th>Data sets</th>
<th>Procedure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Variability of infauna from grab samples</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variability across range of biotopes</td>
<td>All SeaMap records for all years</td>
<td>Non-spatial site/species similarity matrix and MDS plot</td>
</tr>
<tr>
<td>Variability at a very fine scale</td>
<td>2000 data set of replicate samples</td>
<td>Similarity matrix (as above)</td>
</tr>
<tr>
<td>Variability within 1km Boxes</td>
<td>2001 data set</td>
<td>Similarity matrix (as above)</td>
</tr>
<tr>
<td><strong>Spatial patterns of biota within 1km Boxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patterns in similarity of infauna</td>
<td>2001 infauna</td>
<td>Exploratory geographic plots of similarity to mean for each Box</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Similarity/lag plots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moran’s index of dispersion/lag</td>
</tr>
<tr>
<td>Pattern of <em>Sabellaria</em> numbers</td>
<td>2001 numbers of <em>Sabellaria</em></td>
<td>Exploratory geographic plots of <em>Sabellaria</em> numbers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Variance/lag plots</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Moran’s index of dispersion/lag</td>
</tr>
<tr>
<td><strong>Spatial patterns video data within 1km Boxes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patterns of faunal classes</td>
<td>2001 video records</td>
<td>Exploratory geographic plots of faunal classes</td>
</tr>
<tr>
<td>Patterns of sediment classes</td>
<td>2001 video records (supplemented by grab data)</td>
<td>Exploratory geographic plots of sediment classes</td>
</tr>
<tr>
<td><strong>Match infauna from grab samples and video faunal classes</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Match video class and (1) <em>Sabellaria</em> numbers and (2) grab infaunal classes</td>
<td>2001 video records and grab infaunal samples</td>
<td>Cross tabulation</td>
</tr>
<tr>
<td>Match sediment category and (1) infauna and (2) video classes</td>
<td>Summary sediment data (video and grab) and (1) grab infauna and (2) video</td>
<td>Tabulation</td>
</tr>
</tbody>
</table>

**Variability across range of biotopes**

Measurement of variability between grab samples across the range of biotopes from the Wash and its environs can act as a reference for assessing the significance of variability within Boxes. The purpose of stratifying sampling, focusing on the areas likely to support *Sabellaria* biotopes, should have the effect of narrowing the range of variability between samples. For comparative purposes, all grab sample data from previous years were subjected to Multi Dimensional Scaling (MDS) analysis. Details of a hypothetical reference ‘site’ were produced from the average faunal composition of the records with the highest densities of *Sabellaria* and each real data point given a percentage similarity value to this reference datum. These similarity values were interpolated within the coordinates of the MDS plot and contoured (Figure 22).
There are a number of important points shown in this plot to be considered in subsequent evaluation of survey results: (1) the majority of the *Sabellaria* sites were between 65% and 80% similar to the reference site as compared to the much wider range within the complete data set; (2) many sites with lower densities of *Sabellaria* (the blue circles) were still similar in species composition to the high density *Sabellaria* sites. The latter accords with the description of the infaunal composition of the biotopes within the Wash area that many sites had a similar species composition even through *Sabellaria* (which might be considered a structuring species) may have occurred in widely varying densities. The overlap between *Sabellaria* and non *Sabellaria* biotopes might also have occurred spatially.

This range of 65% and 80% will act as a reference against which to judge any spatial correlation between closely spaced samples. It is advisable however, when applying such, to consider if this level of similarity was also found between sites which were close to each other, or if there was a greater variability, indicating heterogeneous distribution of biotopes? This must be considered when assessing the significance of spatial variability.

**Variability at a very fine scale as a further reference for assessing variability within Boxes**

Replicate grabs from the 2000 survey were taken from areas where *Sabellaria* was reported/ predicted to occur. Five replicates were taken positioning the vessel to approximately the same station; it is estimated that the margin of positional error meant that the grabs were likely to be within 150m of each other. This represents the minimum sampling distance. Nevertheless, variability was found to be quite high (Table 10) with an average similarity of only 61.8%.

---

**Figure 22.** A multivariate plot (MDS) of all grab data with sites with more than 20% *Sabellaria spinulosa* shown in red. The contours show the similarity of the samples to a reference ‘site’ derived from the average species composition of sites with high densities of *Sabellaria*. 

Percentage similarity

- 0 - 5
- 5 - 30
- 30 - 40
- 40 - 50
- 50 - 55
- 55 - 60
- 60 - 65
- 65 - 70
- 70 - 75
- 75 - 80
Table 10. Average percentage similarity (between pairs of 5 replicate grab samples taken at 5 stations at 2 sites in 2000).

<table>
<thead>
<tr>
<th>Station</th>
<th>Site name</th>
<th>Mean similarity (%)</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Long Sands</td>
<td>51.6</td>
<td>10.0</td>
</tr>
<tr>
<td>2</td>
<td>Long Sands</td>
<td>66.0</td>
<td>5.6</td>
</tr>
<tr>
<td>3</td>
<td>107 south</td>
<td>63.0</td>
<td>3.2</td>
</tr>
<tr>
<td>4</td>
<td>107 middle</td>
<td>68.8</td>
<td>2.0</td>
</tr>
<tr>
<td>5</td>
<td>107 north</td>
<td>59.4</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Establishing inherent variability is important since any broader scale patterns within the 1km quadrats must be defined by a higher level of variability than this.

Variability of infauna within 1 km Boxes
If the 2001 quadrats are treated as though the 10 samples were randomly chosen replicates, then the average similarity is 59.06% (Table 11), slightly lower than for the inherent, fine scale similarity, but not significantly so.

Table 11. Average similarity between pairs of 10 samples taken within each of the 7 Boxes surveyed in the 2001 survey.

<table>
<thead>
<tr>
<th>Box number</th>
<th>Mean similarity</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>59.38</td>
</tr>
<tr>
<td>1</td>
<td>66.80</td>
</tr>
<tr>
<td>2</td>
<td>63.57</td>
</tr>
<tr>
<td>3</td>
<td>61.31</td>
</tr>
<tr>
<td>4</td>
<td>60.98</td>
</tr>
<tr>
<td>5</td>
<td>57.72</td>
</tr>
<tr>
<td>6</td>
<td>43.63</td>
</tr>
<tr>
<td>Mean</td>
<td>59.06</td>
</tr>
</tbody>
</table>

Spatial patterns of biota within 1km Boxes
Heterogeneity can be explored visually by plotting the samples spatially within the Boxes, coded according to their similarity to the Box average species composition (Figure 23). Clearly, some Boxes are more variable than others, but there is no pattern to the similarity: i.e., when compared to the average sample, the ones most similar are not grouped together, neither are there any obvious trends across any of the Boxes. This is not of surprise considering the relatively small number of samples (statistically) and that in this situation there is no reference to the substratum material.
Figure 23. Grab samples plotted within each of the 7 Boxes colour coded to show their similarity to the average faunal composition for each Box.

**Similarity/ Lag plots**

The similarities between samples have been plotted against the distance separating them (lag distance) in Figure 24. This shows the data from all Boxes and there is very little decrease in similarity over the range of lag distances (50 – 1000 m). A small number of samples were very different from the norm for the Box in which it lay (below 40% similarity) which may have been a result to poor sampling or the inclusion of very different biotopes within the Box. If these are disregarded then the mean and standard deviation of the remaining samples are 61.5% and 15, respectively. It would appear from Figure 24 that there is a spread of similarity values within the range expected from the ground likely to support *Sabellaria*, without any clear indication of spatial auto correlation.
**Figure 24.** Similarity between pairs of samples plotted against lag distance between the pairs. The points for all Boxes have been summarised on the plot.

**Exploratory geographic plots of *Sabellaria* numbers**
Any patterns in the distribution of *Sabellaria* can be explored by plotting grabs coded according to numbers found within each grab (Figure 25). No obvious pattern is apparent in most of the Boxes, although there may be an aggregation of *Sabellaria* in Box 1 and a possible north/south trend in Box 7.
Figure 25. Grab samples plotted within each of the 7 Boxes colour coded to show *Sabellaria* numbers in each grab.

Spatial patterns and patterns of faunal classes in video data within 1km Boxes

The predominant epifaunal communities are shown in Figure 26. The 2 minute recordings covered a very short distance (as measured from the GPS) and although this varied between tows, the average distance was approximately 50m. In the main there was little variation in the epifaunal present and sediment type, although some tows did vary.

The distribution of epifauna varied considerably between Boxes and some showed trends across the Box. There appeared to be a sharp north/south boundary between
barren sand and rich epifauna in Box 7 and a northwest/southeast trend from dense epifauna to sparse *Sabellaria* and epifauna in Box 1.

![Figure 26](image)

**Figure 26.** Video samples plotted within each of the 7 Boxes showing the predominant epifaunal community.

Many of the Boxes were very varied, but Box 5 was characterised by sparse epifauna or barren sediment whilst Box 6 was uniformly dominated by Ophiura and sparse epifauna. *Sabellaria* reefs were observed in Box 4 and, to a much lesser extent, in Boxes 3 and 7. Of particular note is the lack of well developed reef in either Box 1 or Box 7 where reef was observed in previous years up until and including 2000. Since sampling was intensive in this 2001 survey, it is concluded that this represents a real change in reef status between 2000 and 2001.

The reef in Box 4, although extensive, was very patchy with clumps estimated to be no more than a metre across and the ground to be about 75% covered by gravel and sand. Note that well developed reef seen in area 107 (by way of contrast) consisted of many minutes of camera tow where the area was predominantly reef with a few patches of sand interspersed.
Patterns of sediment classes
The predominant sediment classes for the sample sites are shown in Figure 27. The sediments are diverse for most Boxes, although most are gravely sediments. Only Box 6 has predominantly fine sediment samples.

Figure 27. Video samples (supplemented by information from grab samples) plotted within each of the 7 Boxes showing the predominant sediment classes.

Match of video classes to *Sabellaria* numbers and grab infaunal classes
How do video records match up with the grab samples? Can video detect *Sabellaria* successfully? Table 12 summarises (in a cross tabulation) the performance of video sampling as compared to grab sampling. This indicates that *Sabellaria* is very often missed by the video (the red cells), especially where there is dense epifauna. Whilst many of the false negatives are for low densities of *Sabellaria*, some high density populations have been missed. It might be expected that the video would not detect low densities of *Sabellaria* amongst epifauna, but the poor detection in ‘barren’ area is harder to explain.
False positives also occur, but relatively rarely as compared to false negatives. Even well developed *Sabellaria* reefs are characterized by patchiness and one explanation of the false positives is that low density areas amongst the reefs were sampled by the grab by chance.

**Table 12.** The correlation between video classes of epifauna and (1) *Sabellaria* density from grab samples (mean and median values) and (2) classes of infauna. Blue cells highlight mismatch between infaunal *Sabellaria* and video records. Yellow cells indicate acceptable correspondence.

<table>
<thead>
<tr>
<th>Video description</th>
<th>Sabellaria density Mean</th>
<th>Median</th>
<th>Infaunal class</th>
<th>Sabellaria</th>
<th>Ampelisca</th>
<th>Ensis</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense <em>Sabellaria</em></td>
<td>17.70238</td>
<td>19.7614</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Sparse <em>Sabellaria</em> and epifauna</td>
<td>15.21317</td>
<td>11.8211</td>
<td>3</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Moderate <em>Sabellaria</em></td>
<td>11.72838</td>
<td>11.4245</td>
<td>4</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Anemones and epifauna</td>
<td>13.64998</td>
<td>10.3145</td>
<td>4</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Sparse epifauna</td>
<td>8.67241</td>
<td>8.0390</td>
<td>4</td>
<td>2</td>
<td>4</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Dense epifauna</td>
<td>10.40803</td>
<td>6.3291</td>
<td>7</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Barren</td>
<td>13.84166</td>
<td>3.4985</td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td><em>Ophiura</em> and epifauna</td>
<td>0.88572</td>
<td>0.6608</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

**Match of sediment category to (1) infauna and (2) video classes**

*Sabellaria* appears to favour silty, cobbley gravel rather than sandy habitats (Table 13). The dense epifauna on the cobbley gravel habitat as observed on the video may have obscured the *Sabellaria* and this could account for the apparent disparity between cobbley gravel habitats supporting 7 records of *Sabellaria* communities as judged by the infaunal composition as opposed to just 1 record as observed from the video (and 10 epifaunal records).

**Table 13.** Association between *Sabellaria* (1) infaunal class and (2) video class and the sediment type as observed from both the video and the sediment in the grabs.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Infaunal class</th>
<th>Others</th>
<th>Video class</th>
<th>Sabellaria</th>
<th>Epifauna</th>
<th>Others</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobbley gravel</td>
<td>7</td>
<td>5</td>
<td>Silty cobbley gravel</td>
<td>8</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Silty cobbley gravel</td>
<td>6</td>
<td>3</td>
<td>Silty, shelly gravel</td>
<td>6</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Silty, shelly gravel</td>
<td>5</td>
<td>4</td>
<td>Gravel</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Shelly gravel</td>
<td>4</td>
<td>0</td>
<td>Silty gravel</td>
<td>2</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Gravel</td>
<td>3</td>
<td>2</td>
<td>Cobbley gravel</td>
<td>1</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Gravelly sand</td>
<td>3</td>
<td>3</td>
<td>Silty shell sand</td>
<td>1</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Silty gravel</td>
<td>2</td>
<td>6</td>
<td>Gravelly sand</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Silty cobbley sand</td>
<td>1</td>
<td>2</td>
<td>Shelly gravel</td>
<td>0</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Cobbley sand</td>
<td>1</td>
<td></td>
<td>Cobbley sand</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Shell sand</td>
<td>2</td>
<td></td>
<td>Shell sand</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Silty sand</td>
<td>2</td>
<td>3</td>
<td>Silty cobbley sand</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Silty shell sand</td>
<td>13</td>
<td></td>
<td>Silty sand</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>
Summary of variability and spatial patterns as indicated by grab and video samples
The evidence from the grab and video samples suggests:
1. Stratification based on selecting ground likely to support *Sabellaria* decreases the variability between samples considerably;
2. Nevertheless, the variation in (1) the composition of the infauna and (2) *Sabellaria* densities within each Box remains quite high, but no more than might be expected if the samples were designed to be replicates from the same location (within the margin of error of the positioning of the grab);
3. There are no obvious spatial patterns in the Boxes (with perhaps a few exceptions where there is weak evidence for trends across a Box).

The spatial patterns that might be expected to be detected at the scale of resolution of the grab samples would be confined to simple trends across the Boxes and the lack of any clear evidence of such trends does not rule out the possibility of patterns at finer scales. We must turn to remote sensing to pick up finer scale patterns.

Final summary and recommendations
The main conclusions with respect to the use of video sampling design are as follows:
1. Selecting sample areas likely to support substantial populations of *Sabellaria* on the basis of broad scale biotope maps combined with real-time prospecting using AGDS appeared to be successful in that all Boxes selected had at least some samples that contained dense populations and the similarity between the samples from the selected areas was much greater than between the full range of biotopes present in the Wash. In other words, the strategy successfully stratified the area into habitats likely to support *Sabellaria* and associated infaunal communities and those areas less likely to support these communities.
2. Video is the only technique able to determine if well developed reefs are present. Lower growth forms are not detectable by video when they are obscured by rich epifauna. Thus, grab sampling is the only tested way to sample the full range of *Sabellaria* communities.
3. Although there are clear patterns in the distribution of biotopes, spatial patterns at fine scales are hard to quantify. It would appear that there is no spatial correlation between samples separated by distances ranging from the minimum inter-sample distance (approximately 25m) up to 1km, although some spatial trends begin to emerge at the upper distance. A quadrat size of approximately 0.5 km² may be appropriate for a random sampling design.

Discussion
The exploration of spatial variability in the data is necessary at all spatial scales. Broad scale maps (e.g., 1:50-100,000), such as baseline map of the Wash, cannot show the full variability that one might expect to encounter in an area: They present a generalisation (often to the most dominant class, an upper level in a hierarchical structure or some more broadly defined seabed feature). If samples were to be taken within an apparently uniform polygon on the map, then a wide range of other classes may be expected. This range is hard to define statistically since there are often few ground truth data for statistical analysis and the ground may be very variable.

The problem of variability remains at very fine scales (e.g., 1:1-10,000). Thus, variability between even close samples might be high and this it may make the
detection of local patterns very difficult and uncertain. However, the restricted
geographic scale makes replicate sampling more feasible and it may be possible to
pin down the mean, range and variability of the population through sampling such
that populations can be compared statistically. It is easy to integrate data over
quadрат-scales and work with statistics that summarise the nature of the quadрат.

It is the scales between which are most difficult to address. Patches become large
enough to require mapping rather than integration into a summary description and
the processes that drive these patterns start to assume more importance and operate
at the scale of management. However, whilst quite a high level of inaccuracy might
be hidden in broad scale generalisation, this inadequacy becomes very apparent at
the intermediate scale. It no longer suffices for a map to make a statement that
Sabellaria may be expected to be found in an area: the questions ‘how much?’ and
‘how certain?’ become more important.

It has been established that broadscale mapping can be used to identify areas where
Sabellaria spinulosa might be expected to occur, but it is likely that the same
mapping techniques and strategy cannot be successfully used to map at the
intermediate and fine scale heterogeneity, especially in a dynamic environment such
as found in the Wash and its environs. Thus, for condition monitoring, a comparison
of interpreted maps of Sabellaria distribution at intermediate scales would probably
be undermined by high uncertainty and variability. If this is a correct assessment of
the limits to the power of mapping techniques for this application, then an alternative
strategy must be developed. There would appear to be two options: (1) to broadly
define uniform areas (encompassing quite a high level of fine scale heterogeneity)
and to stratify quantitative sampling or, (2) to adopt high definition imaging and
accurate position fixing of samples.

The first option has been explored in this report. Stratified sampling was based on
the random sampling within a quadрат with sides of 1km. The size of the box (quadрат)
is important: too large and the samples will not be from a uniform (or uniformly
patchy) area due to broader scale spatial trends, too small and the samples may not
be representative of a significant area (i.e., be influenced by patchy habitats and
seabed features). Thus, the validity of random sampling as a strategy is based on
the assumption that there is no strong spatial trends within the boxes, although there
may be heterogeneity of biota and even quite large seabed features (as in Box 4).
This may not be true and even within Box 1 that there was a depth gradient and the
north west sector showed more striking evidence of sand extraction than other parts
of the box.

One drawback to this strategy is its restricted spatial coverage. The extent to which
the results from one quadрат reflect wider trends is doubtful: A severe decline in
numbers of Sabellaria and subsequent recovery in one quadрат, for example, may
simply reflect local changes and not be replicated elsewhere. However, is does
indicate that reefs can change significantly at the scale of the quadрат.

The detection of broader spatial trends through replication of the quadрат will have
implications for survey cost. An alternative approach might be the use of widespread
stratified sampling of habitat types. But scattered samples are susceptible to
apparent change through fine scale patchiness and the number of samples required
to obtain any degree of certainty in the results might be quite large. Detection of
temporal changes over a wide area might not be so sensitive to fine scale patchiness, but extraction of significant trends will still require care.

The second option (high definition and precision) might be possible with scanning sonars and acoustic cameras combined with acoustic position fixing devices. The advantages of acoustic techniques over conventional video is their ability to ‘see’ in turbid environments. ROVs have been used for transects over reefs in good visibility and mosaicking high definition video may also offer good quality images suitable for critical analysis and spatial coverage. Head down, as opposed to backward facing video systems also promise greater success in low visibility environments.

9.5 Example 2: Sampling highly heterogeneous areas, Loch Maddy
For further discussion of the use of video for ground truthing in Loch Maddy, see ENV CS06 The use of video techniques for ground truthing.doc

Introduction
A 1998 survey identified areas of high uncertainty and this was taken to be a measure of the heterogeneity of Sponsh Harbour rather than simply a result of poor survey. It was suggested that heterogeneity was at a scale below the spatial resolution of the survey system and that a more statistical approach to sampling and the interpretation of survey data was required.

Heterogeneity creates problems for remote survey when the patchiness of biotopes approaches or falls below the spatial resolution of the survey. The combined inaccuracies of AGDS and ground truth sampling means that there will be a wide spread of acoustic data associated with the life forms resulting in poorly defined acoustic signatures. The scale of heterogeneity is also likely to preclude the ability to re-locate a video in exactly the same patch, an important point for monitoring.

The poor acoustic definition will manifest itself in the likelihood that two or more life forms (or biotopes) will be predicted with very similar levels of probability in heterogeneous areas (see Foster-Smith et al. 1999b). In these situations life forms can only be said to have a statistical likelihood of being associated with the AGDS data rather than a definite association.

However, does heterogeneity present a radically different problem for remote sensing and monitoring or is the problem one of scale? At a more fundamental level, is it important for monitoring programs that patches should be mapped in detail? Alternatively, is it sufficient that heterogeneity be understood and described statistically but with an acceptable level of spatial imprecision? Do heterogeneous areas require special survey protocols?

Methods
Two sample strategies were employed. Firstly, widely spaced samples were taken over the survey area for the purpose of ground truthing the AGDS data. Secondly, two transects in Sponsh Harbour were sampled intensively to provide information on the nature of the heterogeneity of the biotopes.

The positions of the video drops and tows are indicated in
Figure 28. Most of the locations that were used for video tows in 1998 were revisited in 1999 (to within 250m). There were too few coincident sample points in the survey area however, to make a statistical comparison between the 1999 and 1996 data.

![Map](image)

**Figure 28.** Location of Video Takes, labelled by take number. Note the Random sampling across the Outer Loch, and the two belt transects across an area of high heterogeneity at the approach to Sponish Harbour.

**Protocol**

The survey procedure adopted in the 1999 investigation was to take numerous video samples along two belt transects that were located within Sponish Harbour. Both the AGDS and the ground truth data were not treated any differently in the transect areas than elsewhere and the interpretations of the data derived in Section 10 were used in this investigation of the transects. This means that (1) signatures were derived from the whole survey area (not just the transects) and (2) the buffers around the ground truth sample sites overlapped in the transects and increases the likelihood that acoustic data would be associated with more than one sample for signature development.

The video data was used both for ground truthing the AGDS data and separately for a statistical description of the transects. The basic procedures are outlined in Figure 29.
The major new component of the analysis is the statistical treatment of the video sample data. The percentage partial membership values for each of the samples were used to interpolate the probability of each life form over the area covered by the transects. Thus the life forms that might be expected at any one point within the transect will reflect the composition of the surrounding real sample data. The interpolation procedures used were as follows:

- Interpolation package: Surfer version 7
- Algorithm: Inverse distance squared
- Grid size: 25m
- Maximum number of points per interpolated values: 6
- Minimum number: 1
- Search distance: 50m

Search type: simple (i.e., nearest points 6 points if less than 50m in any direction)

The interpolated percentages for all life forms were amalgamated into one table, imported into MapInfo and displayed as pie diagrams.

**Spatial patterns in video biotope data**

Only broad scale trends can be determined from widely spaced point samples or short tows (unless finer scale patterns can be elucidated from the use of the collateral information from higher resolution remotely sensed survey data, which is the justification for remote sensing survey). It would be difficult, in the Loch Maddy trial survey area, to draw more conclusions from widely spaced samples than that there were trends in the distribution of many of the biotopes that were related to the physiographic features of the loch. For example, soft habitats with burrowing megafauna and sea pens were more likely to be found in the outer loch whilst maerl was more common in the shallows of the inner loch. This is meagre information. However, intensive sampling can reveal finer scale trends and patterns and can also show the scale of heterogeneity of an area.
Figure 30. Cluster analysis (nearest neighbour) showing relationship between biotopes based on the occurrence of mixtures from video records.

The two belt transects sampled in Sponish Harbour, each consisted of approximately 25 samples, (approximately three-abreast) across the loch. The partial membership pie charts show a relatively simple picture for the outer transect (Figure 31), with kelp forest close to the shores of Ferramas and En nan Radan/Cnap Ruigh Dubh grading from the southern shore into fine sand, Virgularia and Laminaria saccharina and then a central area of mixed gravel and sand. The ground appeared to be changeable over short distances along the transect, but quite regular across the transect. The inner transect was more varied with faunal turf on rocks and boulders, sand and Laminaria saccharina as well as maerl and gravel occurring over quite short distances in the central portion of the transect.

Figure 31. Distribution and mixture of biotopes across Sponish Harbour for 1999 data, compared to the predominant biotope record for the same area from 1998.
The spatial correlation between the data can be investigated mathematically and this gives an insight into the heterogeneity of the biotope composition of the sea floor as observed by video. Firstly, a geographic distance matrix between each sample was constructed between all the samples in Sponish Harbour from 1999. Pairs of sites were then grouped according to the distance separating them (the ‘lag’ distance) with the groups forming an approximately logarithmic series of increments ranging from 10m to 150m spanning the full range of inter-site distances of 20m to 4km. Secondly, similarity matrices of the sample sites were calculated either using degree of partial membership, or presence/absence of biotopes. The frequency with which pairs of sites in each of the lag groups were similar to another were then counted. A 70% similarity was taken as the cut-off above which pairs were considered to be similar. Figure 32, below, shows the interrelationships between biotopes (grouped into life forms).

**Figure 32.** Schematic diagram showing the interrelationships between biotopes (grouped into life forms). Thin arrows represent weak links and the size of the circles indicates number of samples of each particular life form.

The same calculation was repeated for dissimilarity using 0% similarity as the criterion. These two measures are shown in Figure 33. The horizontal lines show the frequencies for the whole data set. In other words, the further the measures depart from the horizontal line, the more significant the positive or negative correlation. Intriguingly, there appears to be a negative correlation over the shortest distance (<30m) for percentage composition followed by a strong positive correlation from 50m to about 150m. There is a second negative correlation at 200m after which the correlation approaches the average for the data set before falling away at the larger distances.

This pattern is easy to interpret except for the initial negative correlation at very small lag distances. (The calculation was repeated for the whole data set without the tow samples included and the results were similar to those shown in Figure 33 and have not been shown in this report.) The pattern is less marked for presence/absence data, but the initial upturn in correlation is still noticeable. No convincing explanation is offered for this phenomenon but it does seem to suggest that the sea floor is heterogeneous at this very fine scale. However, it would appear that the chances of finding a similar biotope within 150m of any sample were higher than would be had
by chance and this defines the approximate scale of the finest level of homogeneity measured. This probably corresponds with a zone along the transects (e.g., the kelp zone). When distances transcend these zones, correlation then falls.

**Figure 33.** Spatial correlation between samples at increasing lag distances. The horizontal lines show the frequency that could be expected by chance: blue for no similarity, purple for very similar.

**Results and discussion**
The interpolated data has been displayed overlain on the partial membership/fuzzy classification interpretation of the AGDS data (Figure 34). The two interpretations appear to match reasonably well if first and second choices for AGDS interpretation are considered. Both interpretations indicate that the transects are far from uniform in their heterogeneity. Thus, instead of a wide range of life forms predicted to occur throughout the transects, there were clear transitions across the transects involving only a limited range of life forms in each zone.

**Figure 34.** Transect 2: Interpolated Life form composition from video samples overlain on AGDS interpretation (using partial membership/fuzzy classification).
Thus, one of the original ideas for sampling suggested in the 1998 report (Foster-Smith et al. 1999b) does not receive support from the investigation the transects. The approach suggested was to take randomly positioned replicate samples within an area which is treated as being one statistical sampling unit (e.g., a quadrat). However, quadrat sampling will only work if it can be safely assumed that the chance of finding a particular biotope is equal throughout the quadrat. This cannot be assumed where there is a known gradient that the quadrat is likely to straddle (i.e., there is a greater possibility of finding a biotope in one part of the sampling quadrat rather than another). The quadrat approach does not make use of fine scale trends in either the AGDS data or the ground truth samples.

We must be clear, however, exactly what is meant if these probability values (derived either form the video data alone or from the interpretation of the AGDS data). The probabilities do not show the likelihood of finding/not finding the biotope at a location but the chances of finding the biotopes with the predicted frequencies (given a certain intensity of sampling) in the vicinity of the pixel. This introduction of the term ‘frequency’ may seem unnecessary and could be substituted by ‘proportion’. However, strictly speaking the probabilities indicate how frequently a biotope would be expected to be identified (or identified as a partial member of the seabed assemblage) having sampled a number of discrete points within the vicinity of a pixel. Thus, a monitoring program designed to re-sample the transect area should repeat the same intensity of sampling in order to test the frequency of occurrence of the life forms. It would not be a fair test to take a small number of samples and expect the life form found at each to be accurately predicted from the statistical description of that point. However, the samples need not be repositioned with high precision since it is the spatial interpretation of the whole data set that is being compared with previous years and not a sample-by-sample comparison.

Although the interpretation of the sample data can stand alone, the interpretation of the AGDS data provides useful corroboration of the sample data. It is suggested that the selection of the 1st, 2nd and possibly 3rd most likely life forms (as per the protocol in Section 10) gives a good indication of the predicted relative importance of the life forms in heterogeneous areas and this approach has the merit of requiring no extra analysis for other areas. These conclusions and recommendations are tentative at the moment and more work is needed on the characterisation of heterogeneous areas.

Conclusions
In conclusion, it would seem that the optimal sampling size (in the case of these particular transects) lies between 50 and 150m since this corresponds to a level of homogeneity. It is important to target this scale of homogeneity for monitoring since heterogeneous areas are likely to result in widely varying sample composition that makes the detection of underlying change difficult.

The finer level of heterogeneity (below 30m) means that sampling may need to be statistical. For example, it might be possible to say that a particular sampling area

---

1 Note: For distribution maps with very widely spaced ground truth samples the interpretation of probabilities is can be taken as a measure of whether a biotope is/is not likely to be present, although the they should strictly be interpreted as a measure of the likely frequency of finding a biotope IF the vicinity is also increased in size to encompass a statistically valid number of ground truth points.
typically contains kelp, sand and sand with *Virgularia* in a given set of proportions, but that their exact distribution within the zone is unpredictable at the operating scale of the sampling methods used.

There is a more fundamental reason why more detailed analysis of the samples be undertaken, at least in establishing the baseline for a monitoring program. The extent of change can only be properly assessed against good spatial analysis of the records from intensively sampled transects provides information on zones and fine scale heterogeneity that provide guidelines for the intensity of acoustic survey.

### 9.6 Spatial heterogeneity: a special case?

The issue of heterogeneity of the sea floor has been raised throughout this report. There is no doubt that the nature of the sea floor and the biotopes it supports varies considerably over quite small distances in some areas (e.g., Sponish Harbour) whilst in others the sea floor is relatively homogeneous. It will be impossible to map the patches of biotopes accurately if they are smaller than the maximum resolution of the survey. Thus, it becomes important to measure the magnitude and scale of heterogeneity.

**Heterogeneity of the acoustic data:** Variograms give a good indication of the variance in the acoustic data and how this is related to distance between points. Variance increased more markedly over short distances in Sponish Harbour than the outer loch and reached a minor sill between 100-200m before rising again to level off at about 300m which remained at the same level as lag increased. In the outer loch there was a sill at about 400m before variance rose again. The general pattern of variability in Sponish Harbour is of fine scale spatial heterogeneity (up to distances of about 200m) and broad scale homogeneity whereas the outer loch exhibits less heterogeneity over a fine scale, but heterogeneity increases until the scale of the whole outer loch.

**Heterogeneity of the ground truth data:** The estimates of partial membership enabled investigations into patterns of spatial correlation in the ground truth data. The data suggest that there is a negative correlation between samples over very short distances and this is more marked when similarity is measured using an estimate of membership than simply presence/absence of biotopes. In other words, samples which are found close together may or may not share the same biotopes, but if they do the degree to which they are represented is likely to be quite different. This fine scale heterogeneity is not easy to explain without more detailed investigation beyond the scope of this study.

There was a distance over which biotope composition of the samples were likely to be correlated (50-150m) after which the correlation dropped. This lag over which there appeared to be high correlation might correspond with a zone, such as the kelp zone close inshore.

**Heterogeneity of the biotope probability distribution:** Uncertainty in the classification can be calculated and was mapped for the 1998 data (Figure 35). This showed high levels of uncertainty in Sponish Harbour and low levels in the outer loch. It must be remembered however, that uncertainty is based on how much more likely one biotope is to be found than any other, not the expected frequency of finding the component biotopes. Since (as we have seen) biotope mixes predicted from
overlapping signatures are also found in reality, the heterogeneity map is however, likely to represent actual biotope heterogeneity.

![Heterogeneity Map](image)

**Figure 35.** Uncertainty of Classification.

### 9.7 Summary of the pattern of heterogeneity

Both the AGDS and the ground truth samples showed changing patterns of variability with increasing ‘lag’ (distance separating any two AGDS points or video samples). Is there any commonality in the pattern that they both share? AGDS variance increased rapidly from very low variance at distances of about 5m to quite a high variance at about 100m where (at least in Spanish Harbour) variance appears to have levelled off. Variability in the ground truth data was likewise low until 50 to 75m at which distance there was the greatest chance of finding two similar records. Is the point of inflection in the variogram related to the emergence of homogeneity on the sea floor? Likewise, the AGDS variance started to increase at a lag of about 200m whilst ground similarity fell at about 150 to 200m depending upon the index used. Variance levelled off again at (very approximately) 300m, the same lag distance that similarity between samples also started to increase. Is this a coincidence or could
there be some causative relationship at work? At this stage it is difficult to discern, however, for Sponfish Harbour it is suggested, though compounded by alternate scales of heterogeneity and homogeneity.

Positional uncertainty and heterogeneity of the ground compromise classifications of the acoustic data. Whilst it is possible to develop signatures for homogeneous areas, they cannot be applied with confidence to heterogeneous areas since the footprint of the sounder system will result in average reflectance values that will not match to any ‘pure’ signature.

9.8 Implications for video field survey

Good sampling design is crucial for successful image processing. The samples must be:

- Representative of the range of biotopes present,
- Numerous enough for each biotope to be sampled a minimum number of times and,
- Spread throughout the survey area. It is difficult to establish the appropriate levels of sampling required prior to a survey and (as with AGDS survey) it is likely that an initial baseline survey would need to be more intensive than follow-on surveys.

**Video drops versus tows:** Numerous video drops (or very short tows) are preferable to a lesser number of tows for ground truthing for two main reasons:

- The position of the camera is more accurately known (there is less opportunity for the camera to drift away from the boat) and,
- Video records are easier to analyse (one record, one position) and are more consistent (fewer changes over distance).

This is not to say that video tows do not have any use in monitoring: They can show gradations and sharp boundaries much more clearly than drops. The data, however, is not easy to use for ground truthing.

**Analysis of the extracted data:** The initial survey should have the thorough description of the biotope distribution patterns of the survey area as a primary goal. This involves more than the application of routine mapping techniques. This could involve an intensive sampling program with samples taken at varying between-sample distances and the intensive sampling along representative transects. This would allow the investigation of spatial relationships between the samples themselves (i.e., independent of the AGDS data). The framework provided by this analysis would be invaluable as a check for AGDS interpretation and to assess where AGDS interpretation indicates significant deviation from the general biotope distribution pattern.

**Transect Sampling for monitoring change:** Whether intensive sampling along a transect is incorporated into regular monitoring is dependant upon cost. However, intensive sampling provides the only real independent check on the effectiveness of AGDS survey.

**Recommendation:** Heterogeneous areas should be sampled using numerous short video tows. These do not need to be precisely re-located, but should cover the initial survey site comprehensively. The sample area in the Loch Maddy trials was in the
form of transects crossing the main physiographic zones in Sponish Harbour and 20-30 samples were used. Alternative sampling designs (such as squares) could be devised for heterogeneous areas that do not necessarily encompass zones.

10 Guidance on the merits of different tow lengths for habitat mapping

In general it is advised that so long as either a minimum of five replicate samples are taken per ground-type or the recommended area is covered per ground-type as advised by optimal allocation analysis, this should enable the ground-type to be adequately characterised whether by short or long video tows. It is usual practise that within a ground-type, video tows are kept fairly short (e.g. 10 to 15 minutes) or a drop camera is allowed to drift for a similar length of time. This is to ensure that each ‘sample’ can be considered as independent (see above), although as discussed there are methods of sub-sampling long video tows to achieve pseudo-independence that may allow statistical analysis of results. Short tows/drops enable a larger number of sites to be visited over a set time. Water depth obviously affects tow length in practise and if it has taken 20 minutes to reach the seafloor then fewer, longer tows will be favourable to minimise the hauling time. Note that tow length must incorporate stabilisation or settlement time of camera on the seafloor of a 2 to 5 minutes; time for sediment to settle, camera to align to direction of travel (Coggan et al., 2006).

Longer video tows or ROV dives are recommended for detecting/ground-truth boundaries between pre-identified facies. This is to provide adequate evidence that a real habitat boundary exists and to check the location relative to the ground-types map. In some cases habitat boundaries will be very subtle (e.g. muddy sand to clean sand) and long video tows are required to ensure the boundary ‘region’ can be located and characterised. For statistical purposes (see above) boundary detection requires a minimum of 3 replicate tows.

The determination or ground truthing of the location of a boundary between facies will of cause need numerous traverse video tows (Figure 36). Using only video transects this would result in a straight-line assumption along the points of detection, with more transects providing better determination of the edge of change. Where video transects are used to ground truth an acoustically detected facies edge, fewer video transects will be needed, with the aim being conformation of the acoustic discrimination, which will be more detailed.

The area of each ground-type patch needs to be considered prior to ground-truthing, as for some sites patches may be small (e.g. below 100m$^2$) and form a mosaic of ground-types, which will be difficult to ground-truth (both within patch and their boundaries). In such mosaic areas long video tows that are likely to cross a number of such patches are recommended, to confirm that such heterogeneity exists in terms of biotopes and rather than attempting to map every small patch the area should be summarised as a mosaic. In other sites, distinct and large ground-type patches (e.g. over 100m$^2$) may be found, which pose fewer problems for undertaking boundary assessments.
To summarise, it is recommended that within ground-type ground-truthing is driven using a video replication, either through independent tows, sub sectioning of tows or optimal allocation analysis to advise an appropriate number of video tows/drops. Tows should be kept short where ground-type homogeneity is indicated and increased in length with increasing heterogeneity. Ground-truthing of potential habitat boundaries should be considered separately and dealt with using a series of video tows dissecting the acoustic boundary and being longer where this change is not hard-lined, with ideally a minimum of 3 tows per potential boundary between large ground-type patches. Where ground-type mosaics appear of numerous small patches, a few long tows are recommended to confirm that such a mosaic exists in terms of habitats.

11 Scales of acoustic vs. ground truthing sampling and positioning

Acoustic surveys can cover large areas in the order of 100s of km² with sub metre accuracy in the vertical and horizontal planes. The coverage and positioning of video footage is somewhat different. Distances covered by video cameras may range from 10’s to 100’s of metres, while the positioning of footage on the seafloor may be as poor as ±100m working only on calculated layback (considering surveying in 150m water depth, with paid out line of 330m). Using underwater positioning beacons, for instance USBL (Ultra Short Base Line), the position of tow cameras on the seafloor may be more precisely defined. In good circumstances, these may provide positional accuracy of 99.8% of slant range (IXSEA GAPS, 2006) or ±1.5m at 100m; ±2.5m at 1000m; ±9m at 4000m range (Napolitano et al., 2005), depending upon water depth, angle and distance of the camera from the vessel. Triangulation is important and if the beacon is directly, or close to directly below the vessel the angle of intercepting signal will not be large enough to give an accurate directional position.

---

‡ Layback relies solely on Pythagoras theorem of triangulation using depth and paid out line to estimate the position of a deployed instrument behind the support vessel and will not easily incorporate influences of current, tide or vessel movement.
The accuracy of position on the seafloor of video footage and resulting analytical data will affect upon the required (or assumed) accuracy of the classification and survey. Hypothetically, if a boundary between two acoustic facies is targeted, it’s positioning will be very accurate. If the boundary represents a significant change in the character of the seafloor, this will be evident on video footage and will show good correlation. Let us consider however, a situation in which there are several visual changes in seafloor character are seen in the video footage and yet only one apparent in an acoustic classification. In such a situation, the scale of the features and scale of positional inaccuracy may not permit agreement of the visible seafloor feature change and acoustic signature.

More accurate positing systems may be deployed, such as a LUSBL (Long and Ultra Short BaseLine), which combines usually four USBL beacons on the seafloor creating a positional references frame. Such networks however, require further hardware and the deployment expense and may not be justified for habitat mapping. Therefore, we are left with dealing with potential positional uncertainty. To accommodate positional inaccuracy issues into production of accurate habitat mapping from video tows, the targeting of seafloor transects in acoustic classes needs careful consideration and as such, it may be better advised to aim cameras into the middle of large class areas; thus avoiding small areas where the drop may miss the intended target and hence provide inaccurate footage/data for the assumed facies. If a transition between two acoustic facies is the intended target, the chosen transition should be one which has no other apparent transitions in the near vicinity, to avoiding possible mismatching. The verification of an acoustic facies will also be influenced by size; wherein if a facies size (or more critically the shortest axis) falls close to or below the positional accuracy (which needs to comprise the sum of ± horizontal accuracy), it will be below the threshold of identification and may not provide a viable target.

An alternative ground-truthing method, developed in terrestrial and marine settings, is Adaptive Cluster Sampling (ACS), which is especially appropriate for mapping and estimating contiguous or clustered populations and habitat types, i.e., those with a patchy distribution. This sampling approach, in its simplest form, increases the sampling effort in areas where abundance or coverage is above a predetermined threshold value; and the allocation of sampling effort is dependent on the data collected as surveying progresses (Lo, Griffith & Hunter, 1997).

The approach can be applied to transect surveys or random quadrat surveys (Figure 37), where the sampling neighbourhood can be any arbitrary pattern (Lo, Griffith & Hunter, *ibid*). For application on a transect-based survey, when the abundance of a target taxa (count or coverage proportion) is found in a quadrat along the survey line that is above a set threshold value (for instance 60% coverage *Ectocarpus*), quadrat areas *neighbourhoods* to the left and right of the survey line are examined. If their abundances are also above the 80% threshold quadrat areas to the left, right above and below are also examined. ACS programmes provide a time-effective method of surveying elements of the benthos with aggregated distributions; however, they present a more intricate requirement for statistical analysis as the random element of sampling, expected for many statistical tests is no longer valid as sampling is targeted. There are several approaches for accommodating this, such as design unbiased estimators (Dryver *et al*., 1998; Lo, Griffith & Hunter, 1997).
A. Mitchell

Figure 37. Adaptive Cluster Sampling strategies based upon survey transects (left) and random sample quadrates (right) (after Rust and McArthur, 1997).

12 Substratum classification

A key aspect to video interpretation, in addition to the identification and enumeration of benthic species, is classification of the substratum to a formal, recognized classification system. For the EUNIS classification, assessment of both biota and substratum is required for classification to be made (the major physical variables such a hydrodynamic regime, salinity and temperature must also be recognized). The Folk (1954) triangle has traditionally been used by geologists to classify sediments and a modified version of the triangle has been developed to match the EUNIS habitat classifications. The Folk triangle groups the grain or particle size of seafloor material into mud, sand and gravel on the basis of their diameter, with the boundary between mud and sand size grains at 63μm (0.063mm) and the boundary between sand and gravel particles at 2mm. Although the triangle provides guidance to nomenclature, particularly when more than one size fraction is encountered, it is of limited help when interpreting video or stills footage, owing to the inherent difficulty of determining grain size from images covering an area of 0.5 to 3m². As such, a degree of experience is required for an analyst to become proficient and consistent in classifying sediments seen on video footage. Of considerable aid are photographic atlases with standard sedimentological descriptions, such as the ISSIA (Irish Sea Seabed Image Atlas) (Allen and Rees, 1999), and the newly developed MESH Habitats Signatures database (MESH, 2006c). Other simple observations, such as silt thrown into the water column upon the camera platform touching the seabed indicate a significant proportion of fine grains (silt/mud). In addition the biota may indicate the type of substrate, for instance burrows are generally found in fine sand to muddy sediments and attached epifauna such as dead mans fingers (Alcyonium digitatum) require a hard substrate to attach to, which could indicate shell debris or stones (possibly slightly covered by finer sediment) in otherwise fine sediment such as sands and muds.
In some sections of video footage or stills images, it may appear that more than one sediment type is apparent. This is a distinct issue for mixed sediment, which assumes for example a fine sediment fraction consistently or regularly mixed with a coarser sediment fraction such as gravel. This issue is essentially a question of how much of a video frame should consist of a sediment/rock for it to be classified as that substratum? There are few guidelines that directly address this issue, however the general rule of thumb is that it must represent the more significant part of the seafloor in view (i.e. over 50%) for the whole image/footage section to be classified as this substratum. The video analyst must determine and record the chosen threshold and use it consistently throughout the video analysis.

Some habitat classification schemes do detail explicit thresholds, for example Cowardin et al. (1979) used a threshold of over 75% areal coverage of rock or cobbles for the footage to be classified as ‘rock bottom’, or over 25% areal coverage of particles smaller than stones for the footage to be classified as ‘unconsolidated bottom’. Valentine et al. (2005) used thresholds to assess the degree of spatial complexity (an important component of their Marine Sublittoral Habitats classification scheme):

“The percent of the seabed covered by structures was determined by visual observations... and estimated in nine semiquantitative intervals that range from 0 to 100% (0% <1%, 1–5%, 5–10%, 10–25%, 25–50%, >50%, >90%, and 100%). These percent intervals were reasonably easy to estimate from video and photographic imagery. The percent of the seabed covered was determined separately for physical and biological structures, and it was possible that the total percent of the seabed covered by physical and biological structures combined could be greater than 100% (e.g., in the case of abundant attached epifauna on a pebble, cobble, boulder substrate). The degree of structural complexity of the seabed was described in terms of the percent of the seabed that was covered separately by physical and biological structures in seven qualitative intervals that range from none to very high. Wherever more than 50% of the seabed was covered by structures, the structural complexity was considered to be very high.”

It is sometimes advocated to record not only the dominant sediment seen on footage, but also the minor sediment (Joe Bizzaro and Gary Greene, pers. comm.). Like the dominant or major substratum, the minor substratum also requires a threshold to allow consistent interpretation (e.g. less than 40%). This may be particularly pertinent when mixed areas or boundaries are encountered and where there is subsequent difficulty in matching the data to a suitable habitat class.

### 13 The extraction of semi-quantitative and quantitative species abundance data from video/photographic footage: direct counts, visual fast counts and estimates.

A. Mitchell

As previously identified, video and photographic data can be subjected to a number of levels of analysis depending on the initial survey design and the level of information required from the analysis. Any type of analysis will probably require at least two viewings of the video footage, one to assess the quality and determine crude habitat boundaries where applicable and a second, more formal viewing, to apply the decided processing methodology: objectively enumeration, quantification or qualification of contents of the footage. It may be deemed necessary to view the footage on a third occasion, either if the groups to be quantified/qualified are too
numerous to count in one viewing. In this case the “processing” viewings may be divided into a-biological and biological viewings (substrata determination and organism determination, respectively). It is generally recommended for quality assurance that at least 10% of the footage should be reviewed on a further occasion by an independent scientist with suitable experience to verify species identifications and associated abundances, where applicable.

Resulting biological data from video analysis should be stored in a suitable database with appropriate metadata detailing the site, footage identifier, date, time, positional data and then the substrata and species abundance data, plus any other relevant notation (e.g. topography and physical modifiers, proportion of footage processed, proportion independently reviewed, any applied abundance multiplier or transformation). Together, such data will enable classification into appropriate habitats and must be readily imported into statistical analysis packages and GIS.

Qualitative analysis usually involves only a visual interpretation of the material accompanied by some degree of faunal identification. Although it can be achieved quickly and may appear ‘simple’, it relies heavily on the experience of the observer and can therefore be highly subjective. Habitats can be identified to EUNIS levels 3 and potentially 4 and boundaries between habitats can be identified, by sight, on transect surveys. Qualitative analysis is frequently a pre-cursor to any from of quantitative analysis.

13.1 SACFOR and DAFOR abundance data extraction

A relatively rapid method of semi-quantitative analysis is scoring the relative abundance of species on a categorical scale. In the UK, the SACFOR scale (Superabundant, Abundant, Common, Frequent, Occasional, Rare) is often used (Sotheran and Foster-Smith, 2004), having been initially developed by Hiscock (1996) for the UK Marine Nature Conservation Review (see: http://www.jncc.gov.uk/page-2684). Similarly, the DAFOR scale may be applied (Dominant, Abundant, Frequent, Occasional, Rare) (Murphy and Wallace, 2004; Farrell et al. 2005).

In combination with substratum descriptions analysis in this way is appropriate for application of local and national habitat classification schemes (usually down to EUNIS level 5). Care should be taken to standardise sections of video used in assessing SACFOR or DAFOR abundances so they are comparable among video transects (for example, footage duration should be the same and quality should be similar: Section 2). Analysts should keep a working list of species encountered in the footage so abundances may be reviewed systematically throughout the duration of the video transect. Both solitary and colonial epibenthic species may be assessed using SACFOR/DAFOR abundances and the numeric or percentage cover equivalents for each of the SACFOR/DAFOR categories should be used to determine abundance.

Photographic stills or video freeze-frames may be treated as point quadrats and subjected to species counts or percentage cover estimates, providing fully quantitative, semi-quantitative, SACFOR or DAFOR data. An image is often overlain with a physical or digitally generated grid to facilitate counting or estimates of cover
(Service and Golding, 2001; ICES BEWG, 2004). Where the field of view can be calculated, the method can be used to derive measures of absolute species density.

### 13.2 Quantitative data extraction

A. Mitchell

There are several established approaches for fully-quantitative analysis of video footage collected by a transect survey. These all require the length of the transect to be known or calculated (either through the use of an odometer or from the positional data record). Where the field of view remains constant (from a towed video sledge over fairly level ground for instance) and visibility is good, direct counts may be made of all the organisms encountered over a known distance to derive measures of absolute density. Where visibility is poor, a line-transect method may be used (Bergstedt and Anderson, 1990), dividing the image into a number of corridors and making species counts for each corridor. Visibility is assumed to be best in the central corridor and counts made in this sector are taken to be error-free. As visibility is progressively reduced in the outer corridors, the counts are adjusted by a relevant factor to account for animals that may have been obscured by the low visibility.

Where the field of view is constantly changing, through changes in topography, altitude of the camera or visibility and abundances cannot be easily determined, species-time methods may be used to quantify the visual data, counting the number of each species encountered in a fixed time to derive estimates of relative abundance. Published, peer-reviewed literature provides further details regarding these techniques and importantly describes which technique is appropriate given different survey methods and conditions (Michalopoulos et al., 1992; Bergstedt and Anderson, 1990; Kimmel, 1985; Malatesta et al., 1992). Strong et al. (2006) made a comparison between direct/absolute species counts and the species-time method ‘Visual Fast Count’ (VFC), which provides ‘adjusted’ relative abundances for an epibenthic community surveyed using towed video transects (Box 2). No significant differences were found between the two methods, despite VFC being a considerably quicker method of quantitative abundance estimates.
**Box 2. Visual Fast Count**

The Visual Fast Count method estimates abundances based upon sub-sampling video footage; the sub-sample in which taxa first occurs and their abundance. Video footage is divided into five equal time segments. The segment in which a species is first encountered is recorded along with the species abundance, after which that species may be ignored. The abundance of a species is then estimated based upon the recorded count multiplied by a factor relative to the section of encounter.

<table>
<thead>
<tr>
<th>Section of first encounter</th>
<th>Abundance estimate multiplier</th>
<th>Multiplier based upon the ratio of expected frequency of occurrence</th>
</tr>
</thead>
<tbody>
<tr>
<td>First,</td>
<td>5</td>
<td>5/1</td>
</tr>
<tr>
<td>Second,</td>
<td>4</td>
<td>5/2</td>
</tr>
<tr>
<td>Third,</td>
<td>3</td>
<td>5/3</td>
</tr>
<tr>
<td>Fourth,</td>
<td>2</td>
<td>5/4</td>
</tr>
<tr>
<td>Fifth</td>
<td>1</td>
<td>5/5</td>
</tr>
</tbody>
</table>

The predicted values are then converted to relative abundances before statistical analyses are performed.

14 Using photographic stills in conjunction with video footage for habitat discrimination

R. Coggan, A. Mitchell and J. White

Still images are frequently acquired simultaneously with video footage. A separate stills camera, film or digital, can be operated from the surface, the shutter being triggered when items of interest are observed, at random or at regularly timed intervals. The camera can alternatively be programmed to operate automatically, randomly or at defined time intervals.

Photographic stills in most cases provide better image resolution than video footage, and therefore offer an opportunity to identify species that were problematic to identify or unseen on video footage. When taken at timed or random intervals, stills may be treated as ‘quadrats’ samples (see above) and may allow ready enumeration of taxa. Additionally stills are very well suited for illustration purposes in final reporting. The increased ability to identify and enumerate (where required) species from stills images may lead to a more complete assessment of the epibenthic diversity of an area and hence improve the level of habitat classification, however, the use of stills in conjunction with video footage poses problems for any statistical treatment of data and requires some thought as to how the two datasets (video and stills) should be combined for final habitat interpretation.

It is generally advocated that the two datasets are initially treated and presented separately. This includes any subjective classification, statistical analysis and subsequent findings. These should then be used in the final habitat interpretation to inform each other, as and where they cover the same geographic location. For instance, both analysed video data and stills data may be presented as two overlapping shapefiles or geodatabases in GIS and both may be hyperlinked to actual images.
Many scientists use stills images to help identify species that commonly occur on video footage but owing to lower resolution, lighting or image smearing from movement in video footage are difficult to identify with confidence. This can only be undertaken where there is a high degree of certainty that the same species are being observed (for example by freeze-framing the video footage at the exact time/location that the stills image is from and hence showing the same section of seabed, depending on the angular set up of cameras). Stills images are often powerful in enabling the identification of taxa such as sponges, bryozoans and hydroids that are hard to identify even to family level from video footage. Finally, in some situations the more powerful lighting of a stills camera strobe may reveal colours that were difficult to discern on video footage. This may prove particularly important when looking for calcareous and/or red algae such as maerl, or particular sponges.

It is important to ensure that where stills are used to validate video footage, that findings are appropriately applied uniformly across any video data that are to be comparatively assessed. This is to ensure that data are not rendered incomparable, unduly skewed or otherwise corrupted.

15 Database development

J. White and N. Golding

Critical to the value of video footage is its storage and indexing. Creating, collecting and storing metadata in an accessible catalogue is vital to this. Metadata entries created with the footage need to include details of the survey code and name, project code, vessel name, the survey area name, transect name/reference code, start and end positions and times, date, camera and recording system, water depth, vessel speed. Others are detailed in the Video and Imaging techniques Recommended Operating Guidelines (Coggan et al., 2006). These details need to form the indexing system for the video/DVD/electronic storage of footage. Figure 38 shows suggested relationships for indexing a video catalogue.

Figure 38. Video cataloguing index relationships.
16 Interpreting data for habitat classification

R. Coggan and A. Mitchell

Diaz et al. (2004) made a number of statements summarising the enormous and often complex task of integrating datasets that exist at very different spatial scales and levels of detail or accuracy:

“It is clear that the disparity in information density or content between the physical and biological sides of the equation currently hinder applicability and acceptability of benthic habitat mapping effort... The lack of basic information on the biological and environmental tolerances of the species...further clouds the usefulness of any broad-scale mapping attempt.”

“...it is most important that appropriate biological interpretations be applied to the classification of physical substrate types so that biologically/ecologically meaningful habitats are mapped rather than simply substrate type.”

“Emphasis needs to be directed at understanding the complexities of the coastal system functioning rather than simplifying and scaling down the system into smaller components”

Diaz et al. (2004)

As suggested, it is now often the case in many habitat mapping projects that physical data in the form of bathymetry, backscatter and surficial geology derived from multibeam sonar, side scan sonar, LIDAR and similar are often of exceptionally high resolution and quality with good (dGPS) positional accuracy. Complete coverage maps of such data are becoming commonplace and have opened up many possibilities in habitat mapping. The accompanying biological data required to turn a physical seabed map into a habitat map is often however, sparse, of much reduced positional accuracy and often covers less than 1% of the area surveyed by acoustic or remotely-sensed methods.

The assumption that substratum may act as a proxy for ‘habitat’ has become an underpinning theory for habitat mapping, however, in the strictest sense we know that this is not the complete picture and many other parameters derive species distributions that may be needed to fully characterise a habitat. An increased emphasis on ground-truthing, for both sedimentological purposes and biological interpretation is required to improve understanding of how best high resolution physical data may be used to map habitats.

A large body of evidence has shown the links between biodiversity and topography and especially rugosity, slope angle and aspect (Guisan and Zimmermann, 2000) in both terrestrial and benthic systems. Such parameters are readily derived from high resolution bathymetric data and may provide a first overview of the potential habitat distribution in an area. Where any other physical parameters are known, for instance predominant (or residual) current directions, maximum wave base, stratification, etc., with salinity and temperature, this information can go a long way to ‘predicting’ potential habitats. This prediction however, rests upon adequate knowledge of species tolerances and ecological preferences, which may still be poor in many subtidal environments.
It is recommended as standard practise, that the following physical datasets be gathered, derived or estimated:

1. Bathymetry (hillshading from at least 2 different directions also helps visually highlight features)
2. Ground/sediment heterogeneity as possibly revealed using backscatter or ‘roughness’ and ‘hardness’
3. Rugosity (a ratio of real ground area against a planar surface)
4. Slope angles
5. Aspect
6. Prevailing current direction and strength
7. Maximum wave base (an important indicator of energy regime/exposure)
8. Salinity
9. Temperature

Ideally datasets 1 to 5 should be high resolution grids derived from remotely-sensed data. Datasets 6 to 9 may exist as only point measurements and may even be only one point ‘near’ the area of interest.

For interpretation and working these datasets are best presented, where possible, in a GIS platform. Ground-truthing data should derive a series of ‘points’ or possibly ‘lines’ with associated substratum and biological species data. Depending on the assessment of positional accuracy for the ground-truthing, such points or lines should possibly be buffered to indicate such uncertainty. A detailed examination should be made of the underlying physical datasets for each ground-truthing record. This may be performed by linking the datasets through the GIS and summarising the data to examine any trends. In most cases, it would be expected that some trends for at least three of the physical parameters may be related to substratum and species composition. This should then allow the ground-truthing data to be classified into ‘biological’ habitats (e.g. EUNIS levels 4-5), and an interpretation of physical ‘signatures’ of these habitats will allow their occurrence to be predicted in areas without direct ground-truthing data. This should be limited to a certain distance of ground-truthing data. For EUNIS level 3, it may be possible to interpret larger areas of physical datasets even when far away from a ground-truthing station; as such ‘habitats’ are largely physical descriptors with a very limited biological component.

EUNIS habitat classifications in most cases provide characterising species lists and associated SACFOR abundances. This may be readily related to ground-truthing species abundances through direct comparison of species lists. Often a number of very similar alternatives may exist and the associated physical data may help to distinguish which is most appropriate. Replicate ground-truthing samples help provide weight to such decisions; as the biota lists are more representative of the area and have a higher degree of certainty.
17 Statistical classification of seafloor video footage.

J. White

Statistical analysis of video transect data may be used to discriminate habitats in a number of ways, usually by linking defined biological assemblages (epifaunal or infaunal groups determined statistically with univariate and multivariate techniques) to acoustically distinct regions.

Classification of seafloor areas with echo sounders is dealt with elsewhere (Coggan et al., 2006) and will not be discussed in detail here beyond a brief contextual summary. Classification from echo sounder data may be achieved subjectively by eye or objectively using computer routines (commercially available or research developments). Techniques tend rely upon bathymetry (for instance bathymetric terrain modelling, BTM), backscatter intensity (QTC Multiview) or a combination. The examples below demonstrate the analysis of video footage to corroborate acoustic seafloor classifications.

Example 3. Greencastle Codling Bank, Ireland.

C. Vogel and J. White

The Greencastle Codling bank, located off the north coast of Ireland, was surveyed using 95kHz multibeam echo sounder in 2004 and 2005. Three video tows using a sled system were made in 2005, each of 20 minutes duration. Multibeam bathymetric data were used to calculate bathymetric position index for benthic terrain model classification (Weiss, 2001; Lundbald et al., 2006). While backscatter data were used to classify distinctive facies by eye. The subsequent two classifications combined to produce a backscatter-bathymetric compensated habitat classification (Figure 39).

Initial inspections of the entire length of the three video tows produced for each: geological and biological descriptions; species lists with associated DAFOR scale abundances; summary classifications and culminated with; application of a EUNIS habitat codes based upon the observations. This was then followed with quantitative analysis. Five sections of 1 minute duration were randomly chosen along each transect to provide replication from each transect for statistical analysis. Instants chosen for analysis in each video tow were:

- Transect A: 1’00; 4’00; 7’00; 12’00; 17’00.
- Transect B: 3’00; 5’00; 12’00; 13’00; 18’00.
- Transect C: 6’00; 7’00; 8’00; 13’00; 19’00.

Nine taxa common to all transects were chosen and their abundances recorded for each one minute section (sample). For six taxa, direct counts were made and for three, abundance estimates based upon sample counts. Counts and estimates were then related to coverage and reported as abundance/m² (Table 14), enabling statistical comparison between transects. Analysis included: ANOVA of total abundance and species richness, Cluster Analysis, Principle Components Analysis and Detrended Correspondence Analysis.
Figure 39. Classification process of bathymetry and backscatter to produce habitat classification for the Greencastle Codling Bank. Locations of associated video tows indicated.
Table 14. Taxa counts per metre$^2$ from five randomly selected one minute sections of the three video transects made over the Greencastle Codling Bank.

<table>
<thead>
<tr>
<th></th>
<th>Transect A</th>
<th>Transect B</th>
<th>Transect C</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A 1'00</td>
<td>A 4'00</td>
<td>A 7'00</td>
</tr>
<tr>
<td>Dead man's fingers -</td>
<td>A 1'00</td>
<td>A 4'00</td>
<td>A 7'00</td>
</tr>
<tr>
<td>Alcyonium digitatum (count)</td>
<td>0.00</td>
<td>0.07</td>
<td>0.00</td>
</tr>
<tr>
<td>Common Sea Urchin -</td>
<td>Echinus esculentus (count)</td>
<td>0.60</td>
<td>0.27</td>
</tr>
<tr>
<td>Velvet horn -</td>
<td>Codium spp. (count)</td>
<td>0.27</td>
<td>0.13</td>
</tr>
<tr>
<td>Maiden's Hair</td>
<td>Ectocarpus siliculosus (count)</td>
<td>1.33</td>
<td>1.60</td>
</tr>
<tr>
<td>Starfish (count)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Hornwrack (count)</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Common brittlestar -</td>
<td>Ophiothrix fragilis (estimate)</td>
<td>21.30</td>
<td>31.95</td>
</tr>
<tr>
<td>Black Serpent star -</td>
<td>Ophiocoma nigra (estimate)</td>
<td>93.19</td>
<td>111.83</td>
</tr>
<tr>
<td>Crevice brittle star -</td>
<td>Asterias rubens (estimate)</td>
<td>14.64</td>
<td>29.29</td>
</tr>
<tr>
<td>Total abundance</td>
<td>131.33</td>
<td>175.13</td>
<td>130.06</td>
</tr>
<tr>
<td>Taxa Richness</td>
<td>6</td>
<td>7</td>
<td>6</td>
</tr>
</tbody>
</table>
**DESCRIPTIONS:**

**Transect A Description:**

<table>
<thead>
<tr>
<th>Date and time:</th>
<th>22/9/2005, from 15:11:35 to 15:32:31</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time duration:</td>
<td>20:56</td>
</tr>
<tr>
<td>Depth range:</td>
<td>–50 to –48 m</td>
</tr>
<tr>
<td>Latitude/Longitude:</td>
<td>Start point: 55.40025N; 006.94997W</td>
</tr>
<tr>
<td></td>
<td>End point: 55.39604N; 006.95193W</td>
</tr>
</tbody>
</table>

- **Geology:** The north zone of the Greencastle area presents a rather rough material, with mainly pebbles, cobbles and gravels of various sizes composing the seafloor. Abundant sessile benthic organisms in the area include urchins, starfish and shellfish. Few fishes seen.

- **Biology:** This area is characterised by the very high abundance of brittle stars.

**Transect A list of observed events:**

<table>
<thead>
<tr>
<th>Species (fauna)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masked crab – Corystes cassivelanus</td>
<td>Rare</td>
</tr>
<tr>
<td>Broad-clawed Porcelain Crab – Pocellana platycheles</td>
<td>Rare</td>
</tr>
<tr>
<td>Edible crab – Cancer pagurus</td>
<td>Occasional</td>
</tr>
<tr>
<td>Clam - Ruditapes decussatus</td>
<td>Rare</td>
</tr>
<tr>
<td>Common brittlestar – Ophiothrix fragilis</td>
<td>Dominant</td>
</tr>
<tr>
<td>Black serpent-star – Ophiocomina nigra</td>
<td>Dominant</td>
</tr>
<tr>
<td>Crevice brittle star – Ophiopinax aculeata</td>
<td>Dominant</td>
</tr>
<tr>
<td>Common starfish – Asterias rubens</td>
<td>Occasional</td>
</tr>
<tr>
<td>Featherstar – Antedon bifida</td>
<td>Dominant</td>
</tr>
<tr>
<td>Common Sea Urchin – Echinus esculentus</td>
<td>Abundant</td>
</tr>
<tr>
<td>Cockle colony – Cerastoderma edule</td>
<td>Frequent</td>
</tr>
<tr>
<td>Dab – Limanda limanda</td>
<td>Rare</td>
</tr>
<tr>
<td>Dragonet – Callionymiidae</td>
<td>Occasional</td>
</tr>
<tr>
<td>Lesser spotted dogfish – Scyliorhinus canicula</td>
<td>Rare</td>
</tr>
<tr>
<td>Snail shells</td>
<td>Abundant</td>
</tr>
<tr>
<td>Slipper limpet shells – Crepidula fornicata</td>
<td>Abundant</td>
</tr>
<tr>
<td>Dead man’s fingers – Alcyonium digitatum</td>
<td>Frequent</td>
</tr>
<tr>
<td>Common otter shell – Lutaria lutaria</td>
<td>Occasional</td>
</tr>
<tr>
<td>Brown sea cucumber – Asila leferei</td>
<td>Occasional</td>
</tr>
<tr>
<td>Dendrodoa grossularia</td>
<td>Occasional</td>
</tr>
<tr>
<td>Grooseberry sea squirt – Clathrina coricea</td>
<td>Occasional</td>
</tr>
</tbody>
</table>

**Species (flora)**

<table>
<thead>
<tr>
<th>Species</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oar weed – Laminaria digitata</td>
<td>Rare</td>
</tr>
<tr>
<td>Velvet horn – Codium spp.</td>
<td>Abundant</td>
</tr>
<tr>
<td>Maiden’s hair – Ectocarpus siliculosus</td>
<td>Dominant</td>
</tr>
<tr>
<td>Pink encrusting seaweeds – Lithophyllum spp. and Lithotamnion spp.</td>
<td>Abundant</td>
</tr>
</tbody>
</table>

**Transect A summary:**

The south zone of the Greencastle area presents a rather rough material, with mainly pebbles, cobbles and gravels of various sizes composing the seafloor. Abundant sessile benthic organisms in the area include urchins, starfish and shellfish. This result validates backscatter interpretation for the north part of the Greencastle Codling Bank. Few fishes were seen. The EUNIS system classifies this type of substrate as sublittoral mixed sediment. The area was characterised by a very wide brittlestar community forming beds. The main species being *Ophiothrix fragilis* and *Ophiocomina nigra*. Between brittle stars, a mixed fauna extended to complete the composition of this ecosystem. *Echinus esculentus* and the soft coral *Alcyonium digitatum* were among the most frequently observed features. Some fishes were also occasionally observed, such as *Limanda limanda*, *Callionymiidae* and *Scyliorhinus canicula*. From the seabed habitats description by the EUNIS system, this biotope has been identified as the “*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar bed on sublittoral mixed sediment” and is abbreviated as SS.SMX.CMx.OphMx. The parameters of this biotope are indicated below and fit with the area’s pattern of current, salinity and depth:
**Circalittoral mixed sediments:**
*Ophiocoma nigra* and/or *Ophiocomina nigra* brittlestar bed on sublittoral mixed sediment biotope conditions

EUNIS Code: A5.44

**Marine Habitat Classification for Britain and Ireland (v 04.05) SS.SMX.CMx**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity:</td>
<td>Full (30 – 35 ppt)</td>
</tr>
<tr>
<td>Wave exposure:</td>
<td>Moderately exposed, sheltered</td>
</tr>
<tr>
<td>Tidal streams:</td>
<td>Strong, moderately strong, sheltered</td>
</tr>
<tr>
<td>Zone:</td>
<td>Circalittoral</td>
</tr>
<tr>
<td>Depth band:</td>
<td>5-10 m, 10-20 m, 20-30 m, 30-50 ml</td>
</tr>
</tbody>
</table>

**Transect B Description:**

- **Date and time:** 22/9/2005, from 16:35:16 to 16:55:44
- **Time duration:** 20:28
- **Depth range:** –50 to –48 m
- **Latitude/Longitude:** Start point: 55.37631N; 006.84640W
  End point: 55.37250N; -006.84538W

- **Geology:** The area is mainly composed of sandy bed and gavels. It is covered with sand ripples and current was obvious moving the algae.
- **Biology:** Most common features present across the area were crabs, urchins, gastropods and flat fish, however abundances and richness tended to be low.

**Transect B list of observed events:**

<table>
<thead>
<tr>
<th>Species (fauna):</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great scallop – <em>Pecten maximus</em></td>
<td>Frequent</td>
</tr>
<tr>
<td>Spindle shell – <em>Colus gracilis</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Large top shell – <em>Gibbula magus</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Clam - <em>Ruditapes decussates</em></td>
<td>Frequent</td>
</tr>
<tr>
<td>Purple heart urchin – <em>Spatangus purpureus</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Common sea urchin - <em>Echinus esculentus</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Common starfish – <em>Asterias rubens</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Sand starfish – <em>Astropecten irregularis</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Velvet swimming crab – <em>Liocarcinus puber</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Edible crab – <em>Cancer pagurus</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Hermit crab – <em>Pagurus bernhardus</em></td>
<td>Frequent</td>
</tr>
<tr>
<td>Small clear-coloured crab</td>
<td>Abundant</td>
</tr>
<tr>
<td>Circular crab – <em>Atelecyclus rotundatus</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Place – <em>Pleurocetes platessa</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Angler Fish – <em>Lophius piscatorius</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Thornback ray – <em>Raja clavata</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Undetermined sponge</td>
<td>Occasional</td>
</tr>
<tr>
<td>Hornwrack – <em>Flustra foliacea</em></td>
<td>Dominant</td>
</tr>
<tr>
<td>Hydrallmania falcate</td>
<td>Frequent</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species (flora):</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Calliblephoris ciliata</em></td>
<td>Frequent</td>
</tr>
</tbody>
</table>

**Transect B summary:**

The area shows a quite low energy, ‘poor’ environment. There was a decrease in the abundance of embedded cobbles in the sand bed from the start to the end of the video track, suggestive of a transition zone. There was very little apparent sea life but sand geysers show that bivalves were hiding below the surface. According to the EUNIS classification, the seaweed *Flustra foliacea* is characteristic of a circalittoral zone of mixed sediments. Moreover, the associated presence of the soft coral *Alycnium digitatum,* and of the hydroid *Hydrallmania falcate* classifies the area as “*Flustra foliacea* and *Hydrallmania falcate* on tide-swept circalittoral mixed sediment”, abbreviated as SS.SMX.CMx.FluHyd. Physical characteristics match the observed biotope.
Sublittoral mixed sediment:
*Flustra folicea and Hydrallmania falcate* on tide-swept circalittoral mixed sediment biotope conditions

EUNIS Code: A5.444

Marine Habitat Classification for Britain and Ireland (v 04.05) SS.SMX.CMx.FluHyd

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salinity:</td>
<td>Full (30 – 35 ppt)</td>
</tr>
<tr>
<td>Wave exposure:</td>
<td>Exposed, moderately sheltered</td>
</tr>
<tr>
<td>Tidal steams:</td>
<td>Strong, moderately strong</td>
</tr>
<tr>
<td>Zone:</td>
<td>Boulders, cobbles or pebbles with gravel and sand.</td>
</tr>
<tr>
<td>Depth band:</td>
<td>Circalittoral</td>
</tr>
<tr>
<td></td>
<td>5-10 m, 10-20 m, 20-30 m, 30-50 m</td>
</tr>
</tbody>
</table>

**Transect C Description:**

**Date and time:** 22/9/2005, from 17:41:56 to 18:04:05

**Time duration:** 22:49

**Depth range:** –38 to –40 m

**Latitude/Longitude:** Start point: 55.30114N; 006.92557W

End point: 55.29925N; 006.91955W

- **Geology:** Mainly composed of cobbles and pebbles on a gravely seabed. A slight current goes across the area, flowing in an eastward direction.
- **Biology:** The most common features across the transect were anemones, hydroids, urchins, starfishes and scallops. Few fish were identified. The principal alga was hornwrack.

**Transect C list of observed events:**

<table>
<thead>
<tr>
<th>Species (fauna)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolocera tuediae</td>
<td>Abundant</td>
</tr>
<tr>
<td><em>Hydrallmania falcate</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Purple heart urchin – <em>Spatangus purpureus</em></td>
<td>Frequent</td>
</tr>
<tr>
<td>Common sea urchin - <em>Echinus esculentus</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Common starfish – <em>Asterias rubens</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Common sunstar – <em>Crossaster papposus</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Dead man’s fingers – <em>Alcyonium digitatum</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Small, fast moving, white crabs</td>
<td>Frequent</td>
</tr>
<tr>
<td>Common hermit crab – <em>Pagurus Bernhardus</em></td>
<td>Occasional</td>
</tr>
<tr>
<td>Great scallop - <em>Pecten maximus</em></td>
<td>Abundant</td>
</tr>
<tr>
<td>Arctic skate – <em>Raja hyperboreus</em></td>
<td>Rare</td>
</tr>
<tr>
<td>Sea scorpion – <em>Taurulus bubalis</em></td>
<td>Rare</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Species (flora)</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hornwrack – <em>Flustra folicea</em></td>
<td>Frequent</td>
</tr>
<tr>
<td>Kelp – <em>Laminaria spp.</em></td>
<td>Frequent</td>
</tr>
</tbody>
</table>

**Transect C summary:**

This transect was of lower resolution than the other two owing to speed of camera across the seafloor, thus making it more difficult to pick out living organisms or patterns. The area was characterised by the abundance of hornwrack while there were few living organisms around. It was a low energy biotope. No fitting description could be found in the EUNIS classification.
Univariate Analysis:

ANOVA

Aim: to determine if the three sections of seafloor over which video tows were made supported similar species richness and abundances. The null hypothesis (H₀) being that video tows were made over the same biotope supporting the same taxa abundance and richness. The alternative hypothesis, (H₁): video tows do not show the same taxa abundance or richness and are therefore not from the same biotope.

Critical F-value for 0.95% confidence level, Fₜₐₜₐₐ = 3.89. ANOVA results for total abundance give an F-value of 48.19 (Table 15). Thus, F>Fₜₐₐₐ and H₀ is rejected; indicating that video tows were made over areas that did not share patterns of abundance. For taxa richness, F = 51.6 (Table 16). Again F > Fₜₐₐₐ, indicating that the areas of seafloor did not share taxa richness patterns.

Post hoc Least Square Difference (LSD) tests were run to determine which groups of samples contained significantly different mean abundances (Table 17) and species richness (Table 18). These indicate that for total abundance samples from transect A differed extremely significantly from B and C while no significant difference existed between C and B. For species richness again transect A differed extremely significantly from B and C, while B and C were also found to be significantly different.

Table 15. ANOVA results for total abundance among the three video transects.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
<th>Sum</th>
<th>Average</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transect A</td>
<td>5</td>
<td>669.1547</td>
<td>133.8309</td>
<td>1194.219</td>
</tr>
<tr>
<td>Transect B</td>
<td>5</td>
<td>44.48341</td>
<td>8.986682</td>
<td>11.3558</td>
</tr>
<tr>
<td>Transect C</td>
<td>5</td>
<td>66.0492</td>
<td>13.20984</td>
<td>359.7757</td>
</tr>
</tbody>
</table>

ANOVA

Source of Variation | SS        | df | MS       | F         | P-value | F crit |
--------------------|-----------|----|----------|-----------|---------|--------|
Between Groups      | 50294.37  | 2  | 25147.19 | 48.1923   | 1.84E-06| 3.88529|
Within Groups       | 6261.72   | 12 | 521.81   |           |         |        |
Total                | 56556.09  | 14 |          |           |         |        |

Table 16. ANOVA results for taxa richness among the three video transects.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Count</th>
<th>Sum</th>
<th>Average</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transect A</td>
<td>5</td>
<td>30</td>
<td>6</td>
<td>0.5</td>
</tr>
<tr>
<td>Transect B</td>
<td>5</td>
<td>12</td>
<td>2.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Transect C</td>
<td>5</td>
<td>9</td>
<td>1.8</td>
<td>0.2</td>
</tr>
</tbody>
</table>

ANOVA

Source of Variation | SS        | df | MS       | F         | P-value | F crit |
--------------------|-----------|----|----------|-----------|---------|--------|
Between Groups      | 51.6      | 2  | 25.8     | 51.6      | 1.28E-06| 3.88529|
Within Groups       | 6         | 12 | 0.5      |           |         |        |
Total                | 57.6      | 14 |          |           |         |        |

Table 17. Least Square Difference test among video tow sample abundances (** P>0.001)

<table>
<thead>
<tr>
<th>Pairing</th>
<th>Difference</th>
<th>Standard Error</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B - A</td>
<td>-124.94***</td>
<td>14.45</td>
<td>1.68E-06</td>
</tr>
<tr>
<td>C - A</td>
<td>-120.62***</td>
<td>14.45</td>
<td>2.42E-06</td>
</tr>
<tr>
<td>C - B</td>
<td>4.31</td>
<td>14.45</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Table 18. Least Square Difference test among video tow sample taxa richness (* P>0.05; ** P>0.001).

<table>
<thead>
<tr>
<th>Pairing</th>
<th>Difference</th>
<th>Standard Error</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>B - A</td>
<td>-3.60***</td>
<td>0.44</td>
<td>3.53E-06</td>
</tr>
<tr>
<td>C - A</td>
<td>-4.20***</td>
<td>0.47</td>
<td>7.03E-07</td>
</tr>
<tr>
<td>C - B</td>
<td>-0.60*</td>
<td>0.47</td>
<td>0.21</td>
</tr>
</tbody>
</table>
**Multivariate Analysis:**

**Cluster analysis**

Cluster analysis of the video tows indicated two distinct groups and one outlier (Figure 40). Four samples from Transect A (A-1, A-4, A-17 and A-12) show very little difference and were all grouped together (to the top of the graph), while A-7 separated at the first division (placed to the very bottom of the graph), showing no similarity with any other sample. Samples from Transect B grouped with those from Transect C showing similarity between these biotopes.

Cluster analysis of video tows. (Samples from Transect A, B and C labelled with start time of the sample).

**Principal Component Analysis (PCA)**

The fifteen samples from the three video tows were submitted through PCA. Comparison of the (observed) Eigen values for the calculated axis, with their expected Broken Stick counterparts indicated that only PCA Axis 1 contained significant detail. This does not include potential substantial error variance, representing influences affecting few variables or sampling noise (higher observed than predicted Eigen value) (Figure 41). Other observed and Eigen values were, however, similar to their broken stick predictions, with axis 1 to 3 accounting for 80% of the variance (Table 19). Plots of Axis 1 and 2, and 2 and 3 (Figure 42 and Figure 43) show clear separation of samples from Transect B and C and notable separation, although to a lesser extent. Note that the outlier A7 in Figure 42 is also independently grouped in the Cluster analysis (Figure 40).

Cluster analysis of video tows. (Samples from Transect A , B and C labelled with start time of the sample).
**Table 19.** Video tow PCA Eigen values, variance and cumulative variance and predicted and broken-stick Eigen values.

<table>
<thead>
<tr>
<th>AXIS</th>
<th>Eigen value</th>
<th>% of Variance</th>
<th>Cum.% of Var.</th>
<th>Broken stick Eigen value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.851</td>
<td>53.897</td>
<td>53.897</td>
<td>2.829</td>
</tr>
<tr>
<td>2</td>
<td>1.601</td>
<td>17.785</td>
<td>71.682</td>
<td>1.829</td>
</tr>
<tr>
<td>3</td>
<td>0.781</td>
<td>8.683</td>
<td>80.365</td>
<td>1.329</td>
</tr>
<tr>
<td>4</td>
<td>0.766</td>
<td>8.509</td>
<td>88.874</td>
<td>0.996</td>
</tr>
<tr>
<td>5</td>
<td>0.583</td>
<td>6.473</td>
<td>95.347</td>
<td>0.746</td>
</tr>
<tr>
<td>6</td>
<td>0.336</td>
<td>3.736</td>
<td>99.083</td>
<td>0.546</td>
</tr>
<tr>
<td>7</td>
<td>0.057</td>
<td>0.634</td>
<td>99.718</td>
<td>0.379</td>
</tr>
<tr>
<td>8</td>
<td>0.016</td>
<td>0.174</td>
<td>99.892</td>
<td>0.236</td>
</tr>
<tr>
<td>9</td>
<td>0.01</td>
<td>0.108</td>
<td>100</td>
<td>0.111</td>
</tr>
</tbody>
</table>

**Figure 42.** PCA Axis 1 and 2 of video tows.

**Figure 43.** PCA Axis 1 and 3 of video tows.

PCA results indicate that there was a difference in the assemblage patterns among transects and thus in the biotopes. These results validate the visual analysis. With each video transect covering a different type of previously defined seabed type, PCA indicates that the seabed class “Depression on Flat” (Transsect A) differs from “Depression on Low” (Transsect B) and “Steep Slope” (Transsect C) which differed to a lesser degree.

**Detrended Correspondence Analysis (DCA)**

Detrended Correspondence Analysis also produced clearly distinct clusters of samples for Transect A and separate but similar clusters of samples from Transects B and C (Axis 1 and 2 Figure 44; and Axis 1 and 3 Figure 45). As with the Cluster analysis and PCA, samples A 7’00 and B 3’00 appeared as outliers in some views.
Conclusions

All three multivariate analyses tend to the same conclusions. Of the three video transects, B and C are closely aligned, while A clearly differentiates. When considering their locations on the Greencastle Codling Bank, results indicate that areas defined as “Steep slope” and “Depression on Low” share similar epibenthic assemblages while “Depression on Flat” is distinctly different in composition.

Multivariate analyses investigate sample assemblages; the taxonomic compliment of each sample including reference to their abundances. The ANOVAs performed compare only mean sample abundances and taxa richness and showed that significant differences did exist, though not indicating between which samples. Post-hoc LSD tests identified Transect A as significantly different from the other two in terms of total abundance, whereas transects B and C were not found to differ from one another. Similar results were found for taxa richness: Transect A was extremely significantly different from the others (to the extent of P>0.001), while Transects B and C also showed significant differences, but at the much lower significance level of P>0.05).

Both univariate and multivariate analyses corroborate the similarities between Transects B and C and the difference of Transect A. Results suggest that the defined seabed classes “Steep Slope” and “Depression on Low” present similar characteristics, while “Depression on Flat” differs markedly. Integrating results from the visual analysis of video transects and similarities found between Transects C and B; Transect C can be justifiably classified in EUNIS as “Flustra folicea and Hydrallmania falcate on tide-swept circalittoral mixed sediment” – following the EUNIS classification of Transect B.

Of interest is the composition of grab samples from locations close to the video tows (Figure 46). Samples collected near Transect A contained large proportions of coarse material – gravel and pebbles. The two grabs from near Transect B contained primarily coarse sand, while those from the location of Transect C tended to comprise primarily coarse sand, though also contained some coarse gravel. These appear to support the video classifications and similarities, with the larger proportion of sand in the southern and eastern areas.
**Seafloor Video mapping – collection and interpretation**

**Figure 46.** Grab sample photographs, descriptions and locations.
18 Georeference and processing video footage and images

R. Coggan, A. Mitchell and J. White

Positional information giving the location of a camera on the seafloor tends to be derived through one of two approaches: through calculation of layback from the ships position or through USBL positioning beacon. For checking and ensuring accuracy of each of these methods, time-stamping of footage is necessary, especially for linking footage with positional data, where positional overlays on footage are neither available nor suitable. Corresponding video and navigational datasets are indexed based on date and time stamps. It should be noted that by default, some navigational and USBL software take the time code of the computer rather than from the GPS. The difference between this time and UTC should be noted (as usually UTC is recorded on video footage) and preferably computer time should have been set to UTC prior to data recording. All navigational data will require verification and cleaning, which is readily facilitated through viewing data in either GIS or the navigation software, which permits cleaning and removal of positional jumps. The relevant positional data may then be copied for the video footage into a spreadsheet or database along with the associated video notes (station ID, location, camera system, depth, etc.).

Where the only available navigational data has been derived from the support vessel’s GPS, and the camera was on a towed platform, layback should be calculated with simple trigonometry following Pythagoras theorem: using the length of cable deployed (hypotenuse) and the water depth (adjacent). All these measurements should be recorded in the field log; water depth could be taken from high resolution bathymetric data if available. Tidal strength and direction also need to be considered as these may laterally displace the towed gear from the ships track (feathering). Such data, if not recorded in the field, may be obtained from hydrographic office modelled tidal current data (tidal diamonds on Admiralty charts for example). The corrected position will be subject to a moderate degree of uncertainty which can be represented visually by using a spatial buffer. Such a buffer is readily created within any GIS platform. Additionally, footage positions can be ‘referenced’ to notable seabed features that can be seen in the footage and also on high resolution bathymetric datasets (e.g. multibeam sonar). This may be achieved within GIS by manually shifting a shapefile created from the video footage database or by re-drawing the video track by hand within GIS. These methods are highly subjective and may introduce immeasurable errors, however, in some situations this can be an effective way of correcting positional data, especially where stark seabed features, such as bedrock outcrops, are common.

Georeferencing stills images may present more work than georeferencing video footage as most non-digital cameras (and many digital systems) cannot time stamp images, or the stamps are not wanted. Detailed field logs should note the time at which each still was taken and preferably include a brief description of the scene, which then can be used to relate to the navigational data (as detailed above). In some cases, especially with film cameras, additional images are taken by accidental firing of the camera shutter or contact of the camera system with hard seafloor, obstacles for instance; additionally some stills do not come out once processed. In these instances brief descriptions of the scene are useful and where possible stills should be viewed alongside video footage to determine when stills were taken – usually strobe flash can be seen on the video – and the associated time stamp from the video footage used to locate the still image. As with the video footage, such
information should be logged to a spreadsheet detailing other metadata and ultimately the habitat descriptions and species lists. These spreadsheets can be managed through geodatabases through conversion into .csv (comma separated values) text files for incorporation into GIS for overlay upon other datasets. All methods of cleaning and associating positional data with video and stills footage should be well documented and available in final reporting.

18.1 Video mosaicing
There are several computer packages commercially available that will mosaic video footage into a single image. Primarily devised for making panoramic pictures in the horizontal plain from recreational digital cameras, they also work for digital seafloor towed camera footage, creating mosaics in a vertical direction. Data are required to be in an AVI or MPEG format. An example is the software application SnapDV by Tiny Red Monkey Ltd.

18.2 Incorporation of video imagery into GIS
It is now quite possible to incorporate video footage into Geographical Information System (GIS) applications or specially developed dual GIS visualisation software. One such example is Route Mapper Lite. Developed for applications such as quick location of items along road networks (junctions, signs and similar applications), it is also of value for seafloor video tows, providing a window showing the video footage and another displaying any layer which can be imported into generic GIS applications; for example, bathymetric contours, shaded relief, backscatter, features and sample points.

These types of applications, for simultaneously viewing and visualising the location of film footage, can be useful in understanding how the geomorphology and biology relate to bathymetry, relief and its acoustic signature and help to develop an understanding of how boundaries exist in a survey area; if there is a rapid switch or a gentle continuum shift between habitats/biotopes. Usually such applications support play controls – play, stop, fast forward, rewind, pause and slow play – which can be extremely useful in replaying video footage for enumeration of taxa. A development of this breed of applications is the incorporation of “point and click” counting tools or event logging, enabling a variety of organisms to be tagged, counted and summed as they are viewed.

18.3 Event logging and further developments
Event logging software for marine video applications is evolving, for both engineering and biological applications. An example of which is the Auke Bay Laboratory customised version of C-Map Systems’ application VideoRuler 7, (Stone, and Brown, 2005) which includes event logging, enumeration and density estimation tools and scaling, precision measurement and distortion correction tools that rely on laser points in the field of view.

Sigma Scan was used by Kenyon et al. (2005) to measure categorised habitat coverage area recorded by diver towed video. Sigma Scan is a set of adaptive image analysis tools for studying the structure and size of visual information by segmenting and quantifying images. The software has applications in other sciences such as bacteriological cell enumeration, tumour size measurements, determining the projected area of conifer needles and characterising micro structure flaws in steel (http://www.systat.com/products/SigmaScan/#a1).
Figure 47. Screen view of Route Mapper Lite, showing the dual displays of GIS layers and video imagery. Progressive stills (1 to 8) from the westerly video transect over Hemptons Turbot Bank, showing camera progress across a sand wave and evident differences in seafloor structure and material. Note the crab (*Cancer pagurus*) in stills 1 to 3 providing relative image depth, perspective and scale.
The next evolutionary steps in video viewing software may well be in event recognition/development in the capabilities of automated enumeration software in recognising features/organisms and counting them. This is complex and compounded by natural variability in organism structures, sizes, view angles, lighting and focusing, confounding automated shape recognition. The human eye and brain still out match automated techniques.

19 Data storage and archiving: VHS tape/DVD longevity issues

19.1 Magnetic VHS tape storage and archiving

It is important that only good quality Hi Grade VHS tapes from a reputable manufacturer are used for recording and archiving data. If lower quality media is used, expect a lower life expectancy as a consequence. Although the life expectancy of magnetic tape is linked to the storage temperature and relative humidity (RH), it has been demonstrated that humidity is more important. At 20°C (68°F) and 50% RH, an estimated life expectancy value of ~30 years (Van Bogart, 1995) is indicated. If the storage temperature is raised to 25°C (76°F) at 50% RH, the life expectancy is reduced to ~10 years. However, if the humidity is raised to 80% at 20°C (68°F), the life expectancy is reduced to ~5 years.

To maximise the life expectancy of VHS tape, the following recommended practices should be followed:

- Tape should be handled only in no smoking, no food, clean areas.
- Do not drop or subject to sudden shock.
- Keep tape away from magnetic fields (video monitors for example!). Do not stack on top of equipment.
- Tape storage areas should be cool and dry. Never leave cassette tapes exposed to sun (window sills for example).
- Store cassette tapes vertical (like books on a library shelf – on their end).
- Clean the recorder tape path/heads thoroughly as recommended by the recorder/player equipment manufacturer.
- Discard scratched/damaged VHS tapes. These cause significant debris to be left in the recorder tape path.

19.2 DVD storage and archiving

Since the introduction of DVD-R discs in the late 1990’s, there has been much speculation over the longevity of this media. Manufacturers then claimed that consumers could expect a data life span of at least 100 years. With the discovery of media susceptibility to DVD rot however, we now know that disc life may be reduced to just 2 years after it was written. Nowadays, 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 is important however, to remember that there are wide differences between low budget media operations and quality media firms. In addition, variations in manufacturing methods, materials and processes/procedures can dramatically affect the data life of the media you use (http://www.audioholics.com/index.html).

There has been much speculation and conflicting claims on which media are best for data retention of 30, 50, 100 years – green, gold, blue dye or gold/silver reflective
layer. This speculation is somewhat immaterial today. Firms like MKM and Verbatim have developed significantly-improved more sensitive and more stable dyes and reflective materials that virtually eliminate data loss during high-speed read/write processes and enhance long-term reliability.

CD and DVD rot still receives more attention than delamination and oxidation. In reality, unlike earlier LaserDisc rot, CD/DVD rot doesn't affect this media which uses different dye technologies to store data. Delamination and oxidation usually occur at the outer edge of the disc and are often the result of the adhesive not being properly applied and cured during the production process. This usually happens when price-oriented manufacturers use equipment that is 2-3 generations old and the least expensive materials possible. Therefore it is important that for data archiving, you purchase quality media from a quality manufacturer. With the DVD media, the saying “you get what you pay for” certainly applies.

Having said this, it is important to remember that the human being still poses the greatest threat to you data. Exposing DVDs to direct sunlight and intense heat can do dramatic damage. Rapid changes in temperature and humidity can stress the materials. Gravity can bend and stress the discs. Fingerprints and smudges can also do more damage than scratches. Providing you are using quality DVD media from a reputable manufacturer, here are some tips to maximise data life.

Do:
- Handle discs by the outer edge or the centre hole.
- Use a non solvent-based felt-tip permanent marker to mark the label side of the disc.
- Keep dirt or other foreign matter from the disc.
- Store discs upright (book style) in original jewel cases that are specified for CDs and DVDs.
- Return discs to their jewel cases immediately after use.
- Leave discs in their spindle or jewel case to minimize the effects of environmental changes.
- Remove the shrink wrap only when you are ready to record data on the disc.
- Store in a cool, dry, dark environment in which the air is clean -- relative humidity should be in the range 20% - 50% (RH) 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 discs to extreme rapid temperature or humidity changes.
- 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.
19.3 Survey archiving software
Survey archiving software is now appearing in the market place, examples include Video Annotation and Reference System VARS (http://www.mbari.org/vars/), which creates video record annotations to support storage and retrieval of footage. During a survey using VARS “Annotation Interface” frame grabs are taken from footage and associated with annotations. Descriptions are then created using a knowledge base of 3,000 biological, geological and technical terms. Footage is reviewed and annotations extended on return to shore when it is then indexed in VARS “Query interface” and stored in the library.
References


