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Standardising the production of habitat maps in the UK: Seabed Mapping Working Group workshop report November 2015

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Executive Summary

The Marine Strategy Framework Directive (MSFD) (2008/56/EC) requires each Member State to establish targets and indicators designed to guide progress towards achieving “good environmental status”; one of these indicators is “habitat area”. Reporting under the Article 17 of the Habitats Directive (92/14/EEC) has demonstrated that reported changes in habitat area between reporting periods are often not genuine changes and are more often a result of a) different and/or improved mapping methods, b) different and/or improved data and information sources and c) different and/or improved habitat definitions (JNCC 2013). In 2013 a workshop of experts reiterated that these issues would need to be addressed before a habitat area indicator based on real measurements of area change can become operational (Frost *et al* 2013).

To begin to address the first of these issues, Defra funded a piece of work to assess the size of the technical issues and identify potential solutions. The results of the contract can be found in Strong (2015), who identified 39 factors that could lead to different measurements of habitat area for the same section of seabed and 39 potential “uncertainty reduction solutions” (URSs). The majority of these solutions involved the writing of, and adherence to, recommended operating guidelines (ROGs) or standard operating procedures (SOPs).

There are many parties involved in benthic surveying and mapping in the UK and any successful attempt to achieve these recommendations needs to involve all of them in some way. Many of these parties are members of the Seabed Mapping Working Group, which aims to:

- Ensure that the seabed mapping resource in the UK is co-ordinated and meets the needs of all users of marine information.
- Provide a forum for the seabed mapping community in the UK to agree a mechanism for integrated co-ordination of data acquisition and mapping activities to inform national strategic requirements and provide seabed mapping advice across Government.
- Meet the information needs of the UK Marine Monitoring and Assessment Strategy with particular responsibilities to the Healthy and Biologically Diverse Seas Evidence Group, which is responsible for providing technical advice for the implementation of the MSFD.

Therefore, through the Seabed Mapping Working Group the Joint Nature Conservation Committee (JNCC) organised a workshop that aimed to develop a joint plan for carrying out the recommendations of Strong (2015) and developing the URSs. Funds for the workshop came from Defra and were allocated by the MSFD Biodiversity Indicators Research and Development Funders Group. The workshop was held in Peterborough over a day and a half in November 2015.

The workshop focused on eight potential uncertainty reduction solutions (URSs) from Strong (2015), spread across three broad topics:

1. Survey planning.
2. Backscatter collection, processing and interpretation.
3. Habitat map creation.

Breakout groups discussed the URSs related to each of these three topics in turn to explore ways to implement the proposals. Participants were also given the chance to highlight which other URSs are important to prioritise for them/their organisations and provide comments on these. On the second day the group further prioritised the URSs for further discussion and

development. The workshop ended with a plenary discussion led by the chair of the Seabed Mapping Working Group on how to turn the outcomes into a plan of action.

By the end of the workshop the participants had decided to focus on the development of the following URSs:

1. Solution 8: Classification analysis ROG, including elements of Solution 18 Research and ROGs on the standardised calculation and inclusion of derived variables. Products to develop:
    a. literature review examining classification analysis methods for various purposes;
    b. workshop with experts to help formulate the decision tree for the ROG;
    c. ROG for classification analysis.

2. Solution 30: ROG on replicate distribution (specifically the Optimum Allocation Analysis tool). Products to develop:
    a. improvements to the existing Clements *et al* (2010) Optimum Allocation Analysis tool;
    b. review and ROG to cover aspects not covered by the improved tool.

3. Solution 15: ROG for multi-beam echo sounder backscatter collection. Products to develop:
    a. review and comparison of existing standards for backscatter data collection;
    b. workshop to develop guidance;
    c. ROG for the collection of multi-beam backscatter data.

These solutions are each presented in Section 4.2 of this report as a simple project outline, including (i) objectives, (ii) benefits, (iii) products, (iv) exclusions, (v) dependencies and (vi) potential resources. The most popular URS at the workshop (Solution 8: Classification analysis ROG) was also the top-ranked URS in Strong (2015) according to both the potential for uncertainty reduction and its cost-effectiveness.

The next step is to communicate further with organisations that have the skill-sets, resources and/or internal requirements in order to gain commitments on staff time and/or funds towards achieving one or more of the products identified. The Seabed Mapping Working Group will be the conduit for these further discussions and the work to be done will be incorporated into the group's work plan. Group members should be encouraged to notify the group chair of any potentially relevant work that is happening, who can then record these against the relevant objectives in the work plan.

Most of the issues discussed at the workshop are not specific to the UK and other countries may be interested in the development of some of the solutions. Therefore an important conduit for similar discussions at an international level is the Working Group on Marine Habitat Mapping of the International Council for the Exploration of the Seas, through which additional collaborations could be identified.

This report highlights the priorities for marine habitat mapping standardisation in the UK, as agreed by a range of practitioners and users of habitat maps. This work is essential if the UK is to be able to accurately monitor habitat area change in habitats at risk from human activities in the future.

Contents

1 Introduction

1.1 Policy context

The Marine Strategy Framework Directive (MSFD) (2008/56/EC) was formally adopted by the European Union in July 2008. It outlines a transparent, legislative framework for an ecosystem-based approach to the management of human activities which supports the sustainable use of marine goods and services. The overarching goal of the Directive is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment.

The Healthy and Biologically Diverse Seas Evidence Group (HBDSEG[1]) is responsible for providing the technical advice for the implementation of the Directive in the UK with respect to biodiversity. HBDSEG has a number of subsidiary groups, of which one is the Seabed Mapping Working Group (SBMWG), which aims to:

- ensure that the UK's seabed mapping resource is co-ordinated and meets the needs of all users of marine information;
- provide a forum for the UK seabed mapping community to agree a mechanism for integrated co-ordination of data acquisition and mapping activities to inform national strategic requirements and provide seabed mapping advice across Government;
- meet the information needs of the UK Marine Monitoring and Assessment Strategy with particular responsibilities to the HBDSEG.

The Directive requires each Member State to establish targets and indicators designed to guide progress towards achieving GES. Commission Decision 2010/477/EU describes the indicators for which Member States must develop suitable targets and assessment methods (Table 1).

The following targets currently exist related to the (1.5.1) Habitat area indicator in the UK (Defra 2015):

- For special[2] sediment habitats: "at the scale of the MSFD subregions the area of listed (special) sediment habitats is stable or increasing and not smaller than the baseline value (Favourable Reference Area for Habitats Directive habitats). Water Framework Directive extent targets for saltmarsh and sea grass should be used within WFD boundaries as appropriate".

- For predominant[3] sediment habitats: no target proposed.

- For special and predominant rocky and biogenic habitats: "at the scale of the MSFD subregions, area is stable or increasing and not smaller than the baseline value (Favourable Reference Area for Habitats Directive habitats)".

The UK MSFD initial assessment[4] (Defra 2012), based on the evidence collated for Charting Progress 2[5] (CP2), identified major evidence gaps on benthic ecosystems, particularly

[1] The Healthy and Biologically Diverse Seas Evidence Group (HBDSEG) of the UK Marine Monitoring and Assessment Strategy (UKMMAS) is responsible for coordinating and implementing monitoring and observation programmes, covering marine ecosystem health and biodiversity processes.
[2] MSFD *special* habitats include those on the OSPAR list of threatened and/or declining habitats and in Annex I of the Habitats Directive.
[3] MSFD *predominant* habitats are broad-scale habitats that describe the full variety of seabed habitats in the UK, as defined in Table 7 of European Commission (2011).
[4] Article 8 of the MSFD requires that Member States undertook an initial assessment of the current environmental status of that Member State's marine waters by 2012.

related to our overall knowledge on the distribution and area of benthic habitats. The CP2 report stated that we have only interpreted habitat maps from survey data for 10-15 % of the UK seabed.

Table 1: Descriptors, criteria and indicators from the Commission Decision (2010/477/EU) that are relevant to benthic habitats (the criterion and indicator relevant for this workshop are highlighted in bold typeface).

Descriptor	Criterion	Indicator
1 Biological diversity	1.4 Habitat distribution	1.4.1 Distributional range
		1.4.2 Distributional pattern
	1.5 Habitat extent	**1.5.1 Habitat area**
		1.5.2 Habitat volume, where relevant
	1.6 Habitat condition	1.6.1 Condition of the typical species and communities
		1.6.2 Relative abundance and/or biomass, as appropriate
		1.6.3 Physical, hydrological and chemical conditions
6 Sea floor integrity	6.1 Physical damage, having regard to substrate characteristics	6.1.1 Type, abundance, biomass and areal extent of relevant biogenic substrate
		6.1.2 Extent of the seabed significantly affected by human activities for the different substrate types
		6.2.1 Presence of particularly sensitive and/or tolerant species
	6.2 Condition of benthic community	6.2.2 Multi-metric indexes assessing benthic community condition and functionality, such as species diversity and richness, proportion of opportunistic to sensitive species
		6.2.3 Proportion of biomass or number of individuals in the macrobenthos above some specified length/size
		6.2.4 Parameters describing the characteristics (shape, slope and intercept) of the size spectrum of the benthic community

Furthermore, lessons from previous reporting (e.g. under Habitats Directive (92/14/EEC) Article 17 (JNCC 2013)) demonstrate that changes in habitat area between reporting periods are often not genuine changes and are more often a result of a) different and/or improved mapping methods, b) different and/or improved data and information sources and c) different and/or improved habitat definitions.

These are key issues that need to be addressed in order to develop indicators under the Commission Decision (2010/477/EU) criteria 1.4 (Habitat distribution) and 1.5 (Habitat extent) for predominant and special habitats.

1.2 Habitat area indicator development

In 2013, the Joint Nature Conservation Committee (JNCC) and Defra organised a workshop with stakeholders from across the UK. The aims were to identify, define and assess the feasibility of potential indicators of benthic habitat distribution and extent, and to identify the

[5] The UK Government and the Devolved Administrations set out a vision of clean, healthy, safe, productive and biologically diverse oceans and seas. The first UK-wide assessment of progress towards that vision, Charting Progress was published in 2005. Charting Progress 2 was published in 2010 and provides a considerably improved assessment of the productivity of our seas, and the extent to which human uses and natural pressures are affecting their quality.

research and development work that could be required to fully develop these indicators (Frost *et al* 2013).

The workshop developed a set of criteria for assessing whether or not distribution and/or extent indicators would be feasible to develop for various habitats. Robson (2014) provided the list of habitats to use as a starting point, which was composed of broad-scale predominant habitats and special habitats. Criteria included whether pressures are known or expected to cause a change in the area of a habitat and whether a habitat can be feasibly mapped with the array of available techniques. From this, the experts agreed that an area-based indicator may be appropriate for 26 of the benthic habitats (Appendix 1). However, the workshop identified a plethora of technical issues (principally to do with consistency, confidence and repeatability) that would need to be addressed when developing a distribution and/or extent indicator (Frost *et al* 2013).

As a result in 2014-2015 Defra contract ME5318 was arranged to assess the size of the technical issues and identify potential solutions; the results of the contract can be found in Strong (2015). The contract had five objectives:

1. *Identify and summarise the suitability of various survey techniques for mapping the area of the 26 habitats*. Strong (2015) developed a tool to determine the most cost-effective and best performing mapping method for each habitat. This resulted in an objective ranking of methods for a particular habitat, which can be used to steer people towards a smaller pool of methods with the aim of reducing the discrepancy between maps.

2. *Describe the factors that can lead to different measurements of habitat area for the same section of seabed.* Strong (2015) listed and ranked factors in terms of level of uncertainty introduced and how many times they occur in various mapping methods. The most important factors identified were: 1) classification analysis used, 2) sampling resolution, 3) spatial certainty, 4) sample replication and 5) reading error.

3. *Determine ways in which the uncertainty in habitat area and area change calculations may be reduced*. Potential '**uncertainty reduction solutions**' were identified by Strong (2015) for addressing the uncertainty associated with the factors described in objective 2. Each solution was given an efficacy, generation cost and implementation cost. Solutions were ranked by overall impact on their ability to reduce uncertainty over various mapping methods.

4. *For a typical-sized patch of each habitat or group of habitats, give an estimate of the smallest amount of area change detectable using the most suitable techniques and approaches identified in objective 3*. Strong (2015) calculated smallest amount of detectable change as a proportion of the total area of habitat, based on the uncertainty values associated with various factors affecting uncertainty.

5. *Assuming that it would not be possible to map the whole area of each habitat within a sub-region, provide recommendations on alternative approaches to determining the direction and/or amount of change in habitat area within a region*. Strong (2015) proposed some alternative methods, including a stratified survey approach using strata determined by habitat type and pressure intensity.

Following on from the recommendations of Strong (2015) the HBDSEG Benthic Habitats Subgroup proposed two further pieces of work to HBDSEG and the MSFD Biodiversity Indicators Research and Development Funders Group:

1. *Standardisation of mapping methods.* **Aim: to implement the recommendations and guidelines produced within contract ME5318 and promote these among the mapping community.**

   A joint meeting of the Benthic Habitats Subgroup and the Seabed Mapping Working Group in April 2015 agreed that a workshop would be a suitable method to help progress this work. **This workshop occurred in November 2015 and is the focus of this report.**

2. *Next steps for extent indicator development*. Aim: develop an agreed approach to report on the current extent of benthic habitats and change in extent of benthic habitats for the MSFD 2018 assessment.

   The April 2015 meeting also agreed that a workshop would be a suitable method to help progress this work. This workshop occurred in March 2016 and will be described in another report (*in prep.*).

2 Overview of the Workshop

2.1 Aims

Strong (2015) recommended the generation and/or implementation of 39 uncertainty reduction solutions (URSs) for benthic habitat mapping. The majority of these solutions involved the writing of, and adherence to, recommended operating guidelines (ROGs) or standard operating procedures (SOPs)[6]. There are many parties involved in benthic surveying and mapping in the UK and any successful attempt to achieve these recommendations needs to involve all of them in one or more of the following capacities:

1. Writing new guidelines or procedures.
2. Editing existing guidelines or procedures.
3. Carrying out research to develop or update guidelines or procedures.
4. Implementing new or updated guidelines or procedures.

Therefore a workshop was held to gather these relevant parties together in order develop a joint plan for carrying out the recommendations of Strong (2015) and developing the URSs. Through improving the standardisation of the production of habitat maps in the UK, more reliable and consistent maps will develop, with less reliance on the surveyors and/or data interpreters. This in turn will lead to more reliable results for habitat area monitoring studies and allow a more reliable assessment of habitat area change as an indicator of environmental status under MSFD.

2.2 Approach and organisation of the workshop

The workshop was held in Peterborough in November 2015. It was funded by Defra, chaired by Beth Stoker (JNCC), and organised by Helen Lillis (JNCC) with support from Tarquin Dorrington (Defra) and Koen Vanstaen (Cefas). Participants are listed in Appendix 2.

The two day workshop programme (see Appendix 3) comprised context setting, interactive breakout sessions and plenary sessions. The workshop benefited from nominated facilitators for the breakout sessions: James Strong (University of Hull), Sophie Green (British Geological Survey), Markus Diesing (Cefas) and Joey O'Connor (JNCC).

In advance of the workshop participants were requested to read sections of the Strong (2015) report relating to objectives 1 to 3.

2.2.1 Session 1: overview presentations

The scope of the workshop was set out in Session 1 with presentations from the workshop chair, organiser and ME5318 report author on:

- The policy context, background and recent developments – as summarised in Section 1.1 and the first part of Section 1.2 of this report.

- The outcomes associated with objectives 1-3 of the ME5318 report (Strong 2015), as summarised in Section 1.2 of this report.

[6] For the purposes of this report, the following definitions are used:
- Recommended operating guideline: advice on how to carry out a procedure; non-mandatory.
- Standard operating procedure: mandatory instructions on how to carry out a procedure in order to achieve a minimum acceptable level of quality.

It was stressed that this workshop was only the first step in realising some of the uncertainty reduction solutions (URSs) proposed by Strong (2015).

2.2.2 Session 2: developing the uncertainty reduction solutions

For the majority of Session 2 the participants were divided into three groups, focussing on a subset of potential URSs from Strong (2015) that were deemed to be most important or relevant to the participants:

1. **Survey planning** (URS 7, 29 and 30): this topic includes three potential solutions that Strong (2015) ranked relatively highly for their potential for reducing uncertainty in habitat mapping.

2. **Backscatter collection, processing and interpretation** (URS 15 and 17): this topic was chosen for two main reasons:
    a. it was independently featured in the work plan for the Seabed Mapping Working Group for 2015-2016 and therefore would help to achieve that objective;
    b. the workshop coincided with the recent released of the GeoHab Backscatter Working Group report "Backscatter measurements by seafloor-mapping sonars: Guidelines and Recommendations" (Lurton & Lamarche 2015).

3. **Habitat map creation** (URS 8, 18 and 34): this topic includes the solution Strong (2015) identified as having the biggest potential for reducing uncertainty in habitat mapping: URS 8.

i. Topic introductions

The session began in plenary with an introduction to the three broad topics to be discussed in the breakout groups, presented by the group facilitators. The purpose was to give enough background to everybody to enable the most productive discussions in the breakout groups. For each URS in turn, the group facilitators covered:

- What cause(s) of uncertainty[7] is/are being addressed?
- What is the proposed URS?
- What solutions already exist?
- Have there been any recent developments that we can build on or incorporate into the solution?
- How do things work in practice at the moment?

ii. Breakout sessions

The groups then spent an hour discussing each of these three topics before moving on to the next topic and building upon the previous group's discussion. After 45 minutes they moved once again and discussed the final topic for another 45 minutes. Each group was requested to address questions such as:

- What already exists to address this solution?
- Is there any current work happening to address it? (If so, who and what are they doing?)
- What are the benefits and risks of keeping with the status quo versus implementing the solution?
- What would be the most effective/costly/timely solution?

[7] Potential causes of uncertainty are termed "methodological variables".

- Which organisation(s) has/have the responsibility and/or remit to develop this solution (ignoring resource issues)?
- Who has the ability to develop this solution?
- How could this be funded?
- What are some potential milestones for this work (including deadlines)?
- How could the outputs be promoted in the marine community to ensure uptake?

iii. Other important URSs

Before the breakout session the participants considered which other URSs are important to prioritise for them/their organisations and provide any relevant comments. The full descriptions of the URSs from Appendix 4.1 of Strong (2015) were attached to the walls and participants affixed green and red stickers to those they thought should and should not, respectively, be prioritised. Comments were also written on post-it notes and attached to the sheets.

2.2.3 Session 3: next steps

Session 3 began in plenary with a summary of the outcomes of the group discussions and of the comments received about the other URSs. The workshop ended with a plenary discussion led by the chair of the Seabed Mapping Working Group, Koen Vanstaen, on how to turn the outcomes into a plan of action.

3 Day 1 Outcomes: Exploring Problems and Solutions

What follows is a summary of information presented in Appendix 4.1 of Strong (2015) and the discussions from the breakout groups. An overview of the refined potential products and next steps can be found in Section 0.

3.1 Topic 1: survey planning

3.1.1 Solution 7: Optimum selection of mapping methods (existing solution[8])

- What cause(s) of uncertainty is/are being addressed?

  The use of different apparatus for measuring the area of the same habitat can generate a discrepancy. Consistency is critical in monitoring – even more so than picking the best method for each survey.

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

  There are some existing resources to aid the selection of optimum mapping methods in general, such as the Common Standards Monitoring guidelines[9] and the MESH Survey Scoping Tool[10], which directs the surveyor towards certain apparatus depending on the purposes of the mapping and the environmental conditions.

  In addressing objective 1 of the ME5318 contract, Strong (2015) developed a ‘Suitability Tool’, which provides a ranking of the ‘best performing’ apparatus for each of the 26 habitats that were the focus of the report (see Strong (2015) Annex).

- How do things work in practice at the moment?

  There is little documented consensus on the preferred or best apparatus for monitoring different habitats. The choice of apparatus is often compromised by various factors such as (i) what is easier and cheaper to use, (ii) what has worked in the past/previous experience, and (iii) what is available.

- What can be done to develop the solution?

  1. Validate, improve and encourage the use of the ME5318 Suitability Tool. This could include:
     a. validating the tool to ensure the recommended methods are cost-effective and compatible with expert judgement and important historical datasets. This could be carried out using a panel of regulators and/or the conservation bodies;
     b. picking out the top-ranked apparatus for each habitat and translating the recommendations, once validated (as above), into ROGs and/or SOPs for specific activities/habitats;
     c. adding additional parameters to the tool, including survey purpose (i.e. discovery mapping or monitoring) and assessment scale.

[8] Strong (2015) categorised the URSs into “existing” (existing solutions that need wider adoption), “updateable” (existing solutions that need updating) and “new” (solutions that don’t yet exist).
[9] JNCC Common Standards Monitoring: http://jncc.defra.gov.uk/page-2217.
[10] MESH Survey Scoping Tool: www.emodnet-seabedhabitats.eu/default.aspx?page=1822.

Advantages:

- The tool is already available and considers important practical points such as cost and damage to the environment.

Disadvantages:

- The rate of technological development – e.g. over two MSFD reporting cycles – could see apparatus change to the extent that the recommendations are out of date (leading to solution 2).

2. Survey planners/end users could specify the survey parameters required for the production of a map with minimum quality thresholds rather than specific survey apparatus, as currently could be the case with the Suitability Tool – as used in chemical analyses which state required detection limits and units rather than which analytical technique to use. For example, a survey specification could state a required accuracy and density of bathymetric measurements rather than demanding ‘multi-beam echo-sounder’. This provides sufficient flexibility for an operator to use high quality single-beam, satellite bathymetry *etc*. This could include:
    a. survey parameters stated in quantitative terms for remote methods (e.g. resolution (spatial and thematic), units and density of observations) and in more qualitative terms for direct methods (e.g. camera & platform system capable of detecting a 5cm objective on the seabed);
    b. other factors stated, such as survey apparatus that do not contact the seabed.

Advantages:

- This solution has a greater longevity due to it allowing some flexibility in the exact approach to be taken.

Disadvantages:

- Its flexibility could lead to too much variability for monitoring extent change.
- Practical and financial issues are not considered much in this solution.
- It would require substantial reworking of the Suitability Tool.

Other points:

- The specification of some parameters equates to just one apparatus anyway.
- This solution would require a quality assurance scheme to confirm the quality of parameter data – this is currently not in place for many parameters.

3. *Preferred solution*: a combination of solutions 1 and 2. This could include:
    a. changing the Suitability Tool so that it recommends suitable methods based on user-defined survey parameters and quality;
    b. creating guidance document(s) that advise users on survey parameters and quality required for different habitats and different purposes (e.g. monitoring or discovery mapping);
    c. carrying out periodic updates to the Suitability Tool (new format).

Advantages:

- This solution has a greater longevity than solution 1 alone due to it allowing some flexibility in the exact approach to be taken.

- It would lead to greater consistency than solution 2 alone because it would be accompanied by guidance about which survey parameters and quality should be selected.

Disadvantages:

- It would require substantial reworking of the Suitability Tool and production of the habitat-specific guidance.

3.1.2 Solution 29: ROG on sample replication (new solution)

- What cause(s) of uncertainty is/are being addressed?

  A shortage of ground-truthing samples (i) reduces the specificity and certainty of model training and (ii) curtails adequate verification using contingency table analysis. This leads to poorly predicted habitats maps of uncertain accuracy.

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

  The UK Civil Hydrography Programme Survey Specification (MCA 2013) and INIS HYDRO (2013) specify a required amount of replication.

- How do things work in practice at the moment?

  There are three main factors that tend to lead to a shortage of ground-truthing samples for habitat mapping:
  - surveyors do not always know what level of accuracy is required in the final habitat map;
  - the amount of sampling required for different habitat types is not well understood by all surveyors;
  - even if the surveyors know how much replication is required, practical considerations such as time and cost often severely limit the ability to collect the required amount.

- What can be done to develop the solution?

  1. *Preferred solution*: a review and generic guidance that could include:
     a. case studies on the relationship between sample replication and classification accuracy (i.e. power-like analysis of map accuracy verses the replication of ground-truthing);
     b. generic rules for minimum replication level;
     c. some feature-specific rules; and/or
     d. the need for map validation using error/contingency table analysis.

  Advantages:

  - Although built on generalisations, the 'generic rules' are likely to be a clear and pragmatic approach. They are also more likely to be followed when minimum levels are specified.

  Disadvantages:

  - Case studies may be limited by available datasets.

  2. Determine minimum acceptable levels of classification accuracy for end products, depending on the purpose of the survey (i.e. the accuracy of the

final map is measured, using established indices such as kappa, and must meet a minimum threshold to be acceptable).

Advantages:

- It would guarantee a certain level of quality in the habitat map and the area calculations derived from it.
- Specifying a minimum accuracy means that an accuracy assessment must be carried out. This would give the end user a better understanding of the confidence they can have in the habitat map and allow a certain amount of comparison between habitat maps.

Disadvantages:

- This won't often help to increase the number of samples for a particular surveys as assessments of map accuracy often occur once the survey phase has been concluded, i.e. should the map fail to achieve the required level of accuracy it may not be possible to collect more ground-truthing samples.

Other points:

- Bootstrapping is recommended for reducing the need for a separate validation dataset.

3.1.3 Solution 30: ROG on replicate distribution (new solution)

- What cause(s) of uncertainty is/are being addressed?

  Inadequate distribution of ground-truthing samples between classes, between class units and/or within class units (Figure 1) influences the training of models and prediction performance.

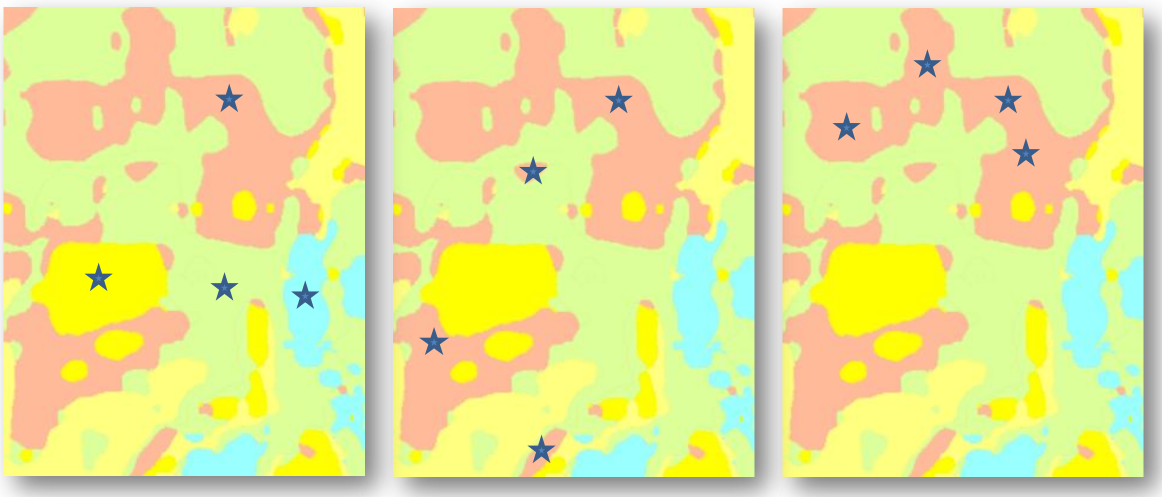

Figure 1: Examples of distributing ground-truthing samples (starred) between classes (left), between class units (middle) and within class units (right).

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

AFBI created the Optimum Allocation Analysis (OAA) tool (Clements *et al* 2010) in 2010 to help allocate sampling effort. Recently, the Norwegian Geological Survey (NGU) has developed a method using an 'Environmental Variability Index' to help allocate sampling effort (van Son *et al* 2015).

- How do things work in practice at the moment?

  The distribution of replication is often subjective, inconsistent and statistically ineffective; existing tools are useful but can be complex to use and have limitations. In addition, the purpose of ground-truthing not always understood – it is for model training and not hypothesis testing.

- What can be done to develop the solution?

  1. *Preferred solution*: a review and guidance that could include:
     a. purpose of ground-truthing, i.e. for model training;
     b. value of stratification;
     c. guidance about statistical and geo-spatial factors that hamper ground-truthing/model training, e.g. spatial autocorrelation;
     d. what can be realistically detected using acoustic datasets,
     e. survey designs (e.g. regular vs gridded stations, mid-polygon vs boundary edges *etc*);
     f. how to provide a fuller 'signature' of habitat occupation; and/or
     g. distribution skewed towards area at risk (within pressure footprint).

  Advantages:
  - This solution was generally considered to be very useful and particularly relevant for sample distribution.
  - The advice is likely to be a useful distillation of current thinking and be a useful reference document for various mapping related activities.
  - The document will remain a working document and be regularly uptake as new science becomes available.

  Disadvantages:
  - Although it provides useful guidance it does not provide any survey planning tools for the objective allocation of ground-truthing between classes and units (see solution 2).
  - The advice is likely to be based on generalisations and may not be appropriate in all situations.
  - More research may be needed before the guidance can be written.

  Other points:
  - More training needs to be carried out by practitioners to ensure best practice is followed. The format of this could be through workshops and/or taught courses.

  2. *Preferred solution*: develop the existing Clements *et al* (2010) OAA tool. This could include:
     a. adding the ability for nesting to cover units of the same class;
     b. making it easier to use; and
     c. potentially adding some default habitats that can be selected from a list.

Advantages:

- OAA is an established and sound method for distributing samples *between classes* (tool already freely available) and *between class units* (with further development required).
- The OAA tool estimates a coefficient of variation as well, which might be useful.
- A best practice document could simply refer to this product for specific elements of survey planning.

Disadvantages:

- The tool isn't currently widely used as it can be cumbersome and only of benefit if it is undertaken between the acoustic and ground-truthing phases of a survey (which is not always possible).

Other points:

- The tool may be more applicable to surveys where the acoustic data has already been collected and processed before planning of sample stations begins.

3. Adopt a method of distributing samples according to environmental gradients present within the survey site rather than classes identified by unsupervised classification.
    a. this would be akin to the Environmental Variability Index method described by van Son *et al* (2015), which is currently in use in Norway's MAREANO project;
    b. this is a novel approach in the UK that would need reviewing for suitability and ecological relevance.

Advantages:

- It does not rely on predefined boundaries within the study area.

Disadvantages:

- It does not consider the ecological relevance of a gradient.

3.2 Topic 2: backscatter collection, processing and interpretation

3.2.1 Solution 15: ROG for multi-beam echo sounder and LiDAR[11] backscatter collection (not processing stage) (new solution)

- What cause(s) of uncertainty is/are being addressed?

  During the data collection phase the main factors influencing backscatter quality include survey hardware, environmental issues (e.g. depth) and the ability to control gain changes during backscatter collection (gain changes are difficult to correct during analysis and generate classification artefacts). Based on the value and high predictive ability of backscatter, this variable is considered highly influential for the quality of acoustic habitat mapping products (Figure 2).

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

[11] LiDAR: Light Detection and Ranging.

There are some standards in the INIS HYDRO (2013) seabed mapping technical specification and some recommendations have been recently proposed in chapter 5 of Lurton and Lamarche (2015). In addition, some organisations develop their own specifications as their experience develops, including Cefas and the British Geological Survey (BGS). There have been recent technological developments, which is likely to lead to more options for optimising backscatter collection with newer systems.

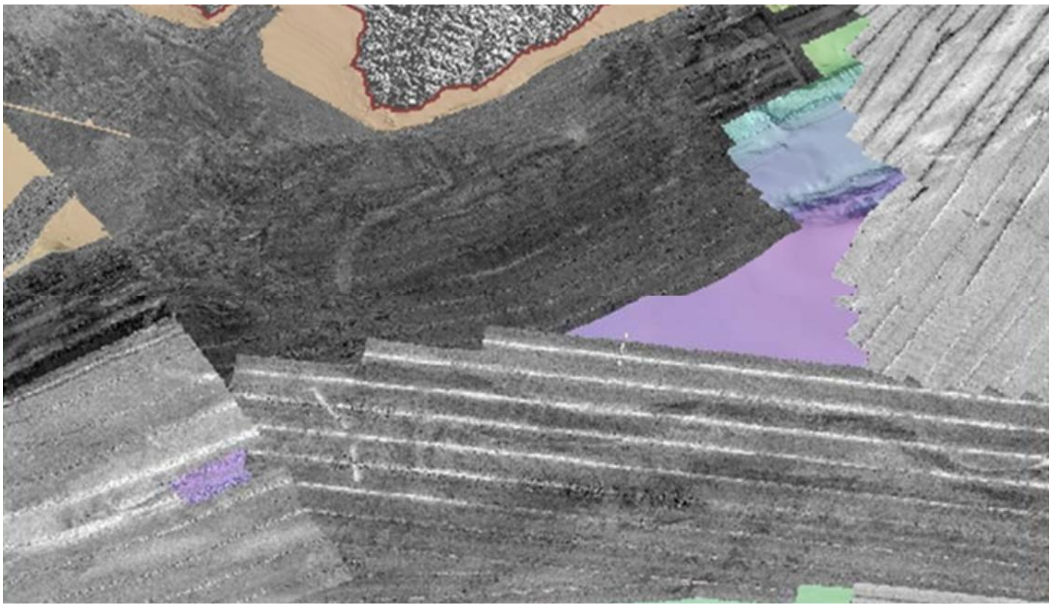

Figure 2: Example of the variation in backscatter intensity that can result from multiple surveys using the same hardware and vessel (taken from Lurton & Lamarche 2015).

- How do things work in practice at the moment?

  Backscatter collection is often not a priority during a multi-beam echo-sounder survey – rather the bathymetry data quality is optimised. This can lead to an area having to be resurveyed to collect better quality of backscatter data if it is of interest to habitat or geological mappers, which is not time- or cost-effective.

- What can be done to develop the solution?

  1. Sharing of and creation of standards and guidelines. This could include:
     a. organisations with backscatter collection specifications (Cefas, BGS) could make their specifications available to others;
     b. a review of these as well as INIS HYDRO (2013) and Lurton and Lamarche (2015) could form a standard document – tailored to cover relevant sections for habitat mapping community;
     c. a study to determine what quality of backscatter constitutes a usable data set for each purpose - i.e. discovery mapping or monitoring.

  Advantages:
  - It may not require too much work to simply distil the information that is already available into an easily digestible document.

  Disadvantages:
  - There is a risk that this standard document could be made too prescriptive as there are too many variables that cannot be standardised (different

hardware, environmental variables, system aging, *etc*). Attention will need to be paid to avoiding this.

2. More engagement with those outside of government to promote the value of backscatter data in seabed mapping. This could include workshops to engage with industry and better communicate the value of backscatter for mapping.

Advantages:

- Higher confidence habitat maps may result for those producing and using them.
- If the data are shared then they are of more use to secondary users too.

Disadvantages:

- The data flow between industry and governmental organisations is limited for marine data. Therefore the effort spent engaging with industry may not subsequently benefit those instigating the engagement if they cannot then access the higher quality data.

3. More communication between habitat mappers and hydrographers to promote understanding of requirements. This could include being specific about whether there are certain habitats that should be targeted/need backscatter to produce mapping.

Advantages:

- It could lead to better value for money, as the data collected by, e.g. the Civil Hydrography Programme, could be used for several purposes. This reduces the chance that an area surveyed for bathymetry would need to be remapped to collect backscatter, which is not good value for money.

Disadvantages:

- It may be difficult to collect backscatter to the desired level of quality while also collecting top-quality bathymetry data that is required for hydrography.

3.2.2 Solution 17: Standardised processing of multi-beam echo sounder data (updateable solution)

- What cause(s) of uncertainty is/are being addressed?

  Bathymetry: Various manual and automated methods are used for multi-beam echo sounder bathymetric data processing. Poor manual data cleaning practice can produce variable results, which can lead to a discrepancy in the reporting of habitat heterogeneity and rugosity parameters.

  Backscatter: The lack of a dedicated backscatter processing method leads to a variety of relatively subjective methods being used, which may lead to discrepancy between datasets.

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

  The UKHO has SOPs for bathymetric processing only. For backscatter, some recommendations have been recently proposed in chapter 6 of Lurton and Lamarche (2015).

It should be noted that increased standardisation of data collection (Solution 15) would improve the input data consistency, which is likely to contribute to the reduction in discrepancy in the end result.

- How do things work in practice at the moment?

  The variety in hardware, software, staff capability and expertise, as well as the different requirements of the end user, all contribute to the variation in approaches and end results.

- What can be done to develop the solution?

  1. Develop a backscatter data processing SOP. If this can also be adopted by the UKHO then there is the potential of habitat mapping efforts benefiting from other multi-beam echo sounder datasets collected for other purposes. This could include:
     a. elements of the Lurton and Lamarche (2015) recommendations; and
     b. a series of generalised case study reports, written by those doing the processing to detail how it was done so others can use as reference materials. E.g. Belfast Lough.

  Advantages:
  - It could be a single point of reference for backscatter processing guidelines in the UK, leading to a more standard approach.

  Disadvantages:
  - The extent to which a standard approach can be followed may be limited; therefore the benefit may not be very great.

  2. Those specifying the survey need to be clear about the purpose (i.e. discovery mapping or monitoring, and if the latter, what amount of change needs to be detected) and define the quality that is required from the backscatter data, e.g. the aim could be to create a single use map, which requires a high contrast, artefact-free backscatter image using relative dB values to identify and classify substrate boundaries with ground-truthing.

  Advantages:
  - Coupled with a guidance document about what to do to meet the various end needs (previous point), this could help guide the processor towards the most suitable method for processing.

  Disadvantages:
  - This relies on the end user being able to articulate the specific requirements from the backscatter; however, this might not require too much knowledge from the end user if the guidance is good enough to allow the processor to determine the likely specific requirements from what the end user says.

  3. Develop a quality control scheme for backscatter processing, akin to the Northeast Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme[12]. This could include an inter-calibration/common dataset exercise.

[12] The NMBAQC scheme provides a source of external quality assurance for laboratories engaged in the production of marine biological data. In the United Kingdom all Competent Monitoring Authority laboratories and their contractors undertaking statutory marine monitoring programmes are required to participate.

Advantages:

- It would be possible to assess the variation that can result from different approaches to backscatter data processing.
- Contractors and other organisations would be signing up to following some agreed procedures.

Disadvantages:

- There may not be much enthusiasm for a common dataset exercise.
- Discrepancies may be software-related rather than user-related.
- This may be resource-intensive and require cross-agency cooperation to establish. It would therefore benefit from a high-level steer.

3.3 Topic 3: habitat map creation

3.3.1 Solution 8: Classification analysis ROG (new solution)

- What cause(s) of uncertainty is/are being addressed?

  Different classification analysis methods can lead to different resultant habitat maps (e.g. Figure 3). There is no universal analysis method for all possible situations and it is not possible to know beforehand which method will be most appropriate.

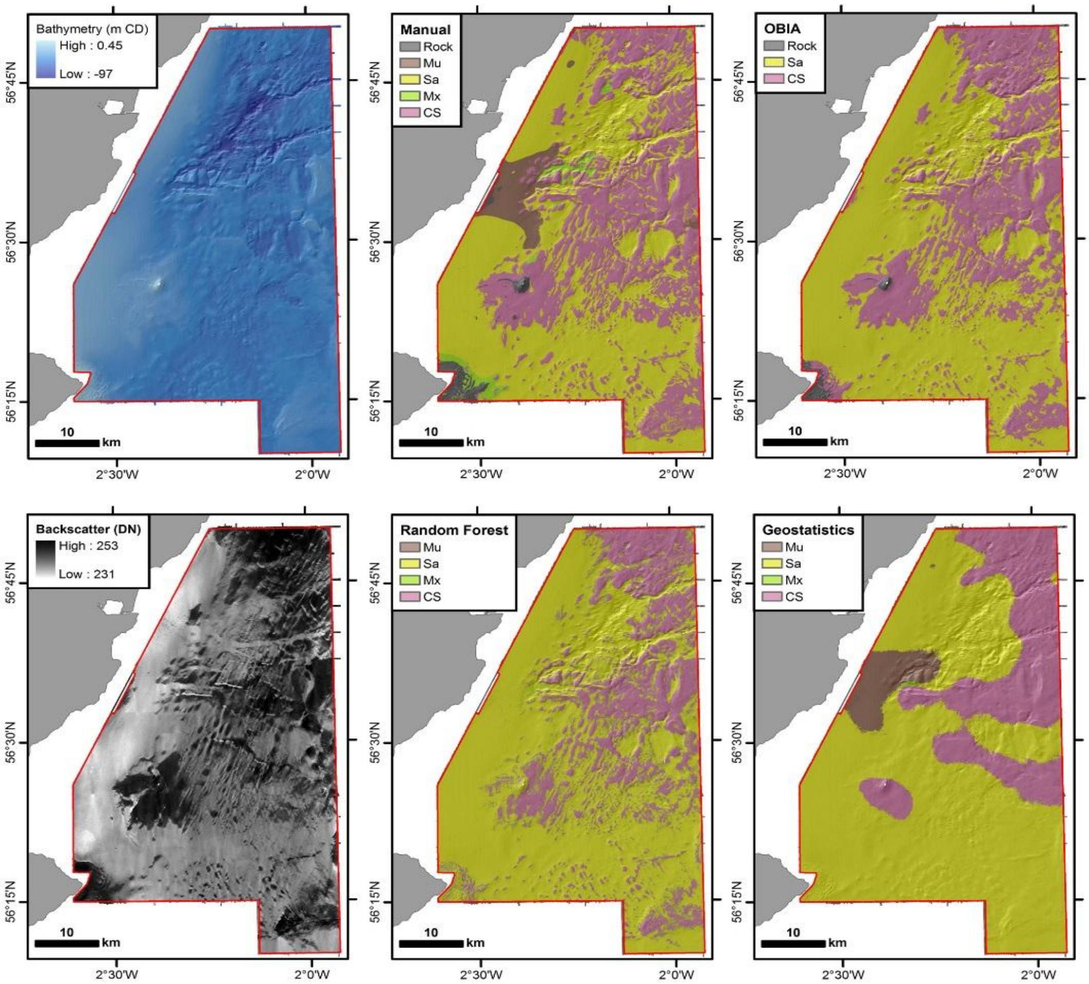

Figure 3: Example of the different seabed maps that can result from different classification methods (taken from Diesing *et al* 2014).

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

  There is currently limited guidance about this, as it is a developing field.

- How do things work in practice at the moment?

  Approaches often vary depending on the experience and expertise of the mapper, rather than an assessment of the best approach for the situation.

- What can be done to develop the solution?

  1. ROG should be written that advises on classification methods. This could include:
     a. a decision tree for choosing the best analysis method depending on the habitat, the input data, the purpose (e.g. discovery mapping or monitoring), *etc*. This may be developed through:
        i. literature review (including terrestrial remote sensing);
        ii. workshop with experts (potentially including terrestrial remote sensing experts).
     b. instructions on the need for all habitat maps to be accompanied by some form of quality estimate that states the classification success associated with a map, including:
        i. publication of two or more accuracy measures;
        ii. overall and class-specific measures;
        iii. publication of associated confidence limits; and/or
        iv. provision of an error matrix/contingency table.
     c. guidelines on a multi-method ensemble approach (Diesing & Stephens 2015) for discovery mapping.
     d. instructions to provide detailed metadata on the method and variables used.

  Advantages:
  - More standardisation in the use of classification analysis among the habitat mapping community, leading to habitat maps being more comparable. This could be useful for monitoring habitat area change.
  - Users are more likely to choose the most appropriate method and variables for classification analysis, leading to higher quality habitat maps.

  Disadvantages:
  - This is a developing field, meaning that the guidelines may go out of date relatively quickly; they will need to be regularly reviewed and updated.

  Other points:
  - The guidelines should not be too prescriptive, as there is still a lot of development happening.
  - For monitoring, it is important to be consistent with analysis methods, but different habitats might require different methods.
  - Regarding point d – this would be more likely to occur if the MEDIN metadata standard allowed for additional theme-specific fields.

  2. Develop a quality control scheme for habitat mapping, akin to the NMBAQC scheme. This could include an inter-calibration/common dataset exercise.

Advantages:

- It would be possible to assess the variation that can result from different approaches to classification.
- Contractors and other organisations would be signing up to following some agreed procedures.

Disadvantages:

- This may be resource-intensive and require cross-agency cooperation to establish. It would therefore benefit from a high-level steer.

3. Carry out more comparative studies on classification performance – specifically on marine acoustic data.

Advantages:

- This would further the development of classification methods and increase awareness of the differences that result from different methods.

Disadvantages:

- This may be a lower priority compared with some of the other solutions.

3.3.2 Solution 18: Research and ROGs on the standardised calculation and inclusion of derived variables (new solution)

- What cause(s) of uncertainty is/are being addressed?

  It is possible to derive many variables from a single bathymetry dataset, e.g. slope, aspect, rugosity, *etc*. These variables can be calculated at many scales. The use of these derived variables in the classification of continuous data for habitat mapping can vary leading to variation in the resultant habitat map. The addition of too many derived variables can result in model 'over-fitting' and poor map confidence.

- What solutions already exist and have there been any recent developments that we can build on or incorporate into the solution?

  Building on the multiscale terrain analysis of Wilson *et al* (2007), Dolan *et al* (2012) provide standardisation for the calculation of derived variables for seabed terrain characterisation. Lecours *et al* (2015) have recently published a review paper on spatial scale in habitat mapping. In addition, various generic methods for variable selection exist, e.g. the Boruta algorithm (Kursa & Rudnicki 2010). Knowledge can also be transferred from other science disciplines e.g. pattern recognition and remote sensing.

- How do things work in practice at the moment?

  Derived variables are often included in classification analysis with little thought for their relevance or appropriate scales.

- What can be done to develop the solution?

  1. Carry out further research on the use of derived variables for habitat mapping. This could include:
     a. case studies that test a range of spatial scales (will depend on feature or habitat of interest); and

b. identification of the appropriate derived variables for particular habitats.

Advantages:

- This could lead to a better understanding of the suitability of various derived variables (and their scales) for various seabed habitats.

Disadvantages:

- Methods for variable selection already exist; there may be enough existing knowledge that can be drawn upon from other disciplines.

2. Develop a ROG containing an objective derived variable selection process. This could include:
   a. how to choose the appropriate spatial scale(s) at which to calculate the variable;
   b. how to select the appropriate variables;
   c. variables derived from backscatter as well as bathymetry;
   d. specifying the variables to use for particular habitats; and/or
   e. instructions to provide information on derived variable used in the habitat map metadata, including justification.

Advantages:

- This could increase awareness of the differences that result from different derived variables and lead to more standard habitat mapping approaches and higher quality resultant maps.

Disadvantages:

- More research may be needed before the guidance can be written.

Other points:

- The selection of variables is more important than the scales used to derive those variables.

3.3.3 Solution 34: Guidance on the selection and use of interpolation (new solution)

Although this topic was touched upon, it was deemed relatively unimportant and time did not allow for the workshop participants to build on the solution proposed by Strong (2015); therefore it is not discussed further in this report.

3.4 Which other URSs are important to prioritise and what can be done?

31 of the 39 URSs in Strong (2015) were not discussed in the breakout sessions; therefore the participants were given the chance to express their views on the relative importance of these other solutions, allowing comparison with the rankings determined using the standard criteria for potential performance and cost-effectiveness in Strong (2015).

Tables from Appendix 4.1 of Strong (2015), which described the details of the additional URSs, were attached to the walls around the room. Participants were provided with stickers and post-it notes and were asked to attach green stickers to the solutions they thought were important, red stickers to solutions they thought were less important and post-it notes containing comments to any of the solutions.

A summary of the results of this exercise is shown in Annex 4, which contains:

- The number of green and red stickers per URS,
- Comments from the post-it notes,
- A ‘net approval’ score created by subtracting the number of red stickers from the number of green stickers, and
- A rank created by putting the ‘net approval’ scores in descending order.

The most popular additional URSs are described below. Note that performance and cost-effectiveness ranks from Strong (2015) are out of 39 – the total number of URSs – and the rank based on stickers is out of 31 – the number of URSs considered in this exercise.

3.4.1 Solution 19: ROGs for benthic sampling (existing solution)

This was the top-ranked additional URS based on the number of green stickers (8) compared with red stickers (0). Strong (2015) ranked this solution 20th for performance and 11th for cost-effectiveness. As Strong (2015) classes this as an ‘existing’ solution the participants discussed what more could be done to develop this solution. Suggested improvements to the existing MESH Atlantic ROG for grab sampling (Guerra & Freitas 2013) include:

- Guidance on specific grab types to use for particular habitats.
- Updates to reflect the latest technology, such as the use of camera grabs.

3.4.2 Solution 3: Habitat and gap resolution catalogue (new solution)

This was ranked joint-second based on the number of green stickers (7) compared with red stickers (0). Strong (2015) ranked this solution 2nd for performance and 20th for cost-effectiveness.

This solution was not discussed further at the workshop due to a lack of time; however, Strong (2015) describes a solution that would:

1. "Catalogue the appropriate sampling and analysis resolution required for specific habitats;
2. “Catalogue the appropriate sampling resolution required for the confident detection of gaps [in a patch of habitat] ([due to] anthropogenic sources);
3. “[Lead to] consisten[t] use of the same sampling and analysis resolution between surveys of the same habitat type.”

3.4.3 Solution 32: New NMBAQC epibiota scheme component (new solution)

This was ranked joint-second based on the number of green stickers (8) compared with red stickers (1). Strong (2015) ranked this solution 5th for performance and 19th for cost-effectiveness.

This solution was not discussed further at the workshop due to a lack of time; however, Strong (2015) describes a solution that would:

1. “Reintroduc[e] the NMBAQC epibiota ring test;
2. “Specify contractor participation with the NMBAQC epibiota ring test within survey specifications;
3. “Encourage in-house QC in survey specifications.”

Written comments from participants were:

- “for monitoring [this] needs to lead to a pass/fail standard.”
- “[this is] very important for consistency across contractors in industry. [It] could go further to implement NMBAQC scheme for review of overall maps.”

3.4.4 Solution 35: Guidance on the collection of stills photography (updateable)

This was ranked joint-second based on the number of green stickers (7) compared with red stickers (0). Strong (2015) ranked this solution 39th for performance and 21st for cost-effectiveness.

This solution was not discussed further at the workshop due to a lack of time; however, Strong (2015) describes a solution that would:

1. "Provide guidance on collection frequency for photographic stills.
2. "Provide guidance on [what] the trigger [should be] for [photographic] stills collection."

Written comments from participants were:

- "[The most appropriate guidance] might be a minimum [number of stills, n,] to reach a species discovery threshold rather than a specific number, [e.g.] n >= 5".
- "[The updated guidance could cover] post-survey selection of images".

4 Day 2 Outcomes: Refining the Solutions and Identifying Next Steps

Day 2 of the workshop began with the group facilitators presenting a summary of the previous day's group discussions (summarised in the previous Section). Afterwards, there was a plenary discussion and a series of next steps were identified. The outcomes of this are presented here.

4.1 Prioritising solutions

After hearing the summaries of the breakout group discussions the participants were asked to vote for three solutions to focus on for the remainder of the plenary discussion at the workshop by affixing green stickers to a flip-chart that listed the solutions. The results were:

Solutions that were discussed further at the workshop:

1. Solution 8: Classification analysis ROG, including elements of Solution 18 Research and ROGs on the standardised calculation and inclusion of derived variables – **22 votes**
2. Solution 30: ROG on replicate distribution (specifically the OAA tool) – **12 votes**
3. Solution 15: ROG for multi-beam echo sounder and LiDAR backscatter collection (specifically multi-beam echo sounder) – **11 votes**

Solutions that were not discussed further at the workshop:

4. Solution 7: Optimum selection of mapping methods (specifically the Suitability Tool) – **10 votes**.
5. Solution 29: ROG on sample replication – **6 votes**
6. Solution 17: Standardised processing of multi-beam echo sounder data – **2 votes**

4.2 Solutions discussed further at the workshop

The text below is a summary of the conclusions drawn from the breakout group sessions and the subsequent plenary discussions regarding next steps for developing the solutions. The solutions are each presented as a simple project outline, including (i) objectives, (ii) benefits, (iii) products, (iv) exclusions, (v) dependencies and (vi) potential resources.

4.2.1 Solution 8: Classification analysis ROG, including elements of Solution 18 Research and ROGs on the standardised calculation and inclusion of derived variables

i. Objectives

1. Provide guidance for the selection of appropriate classification analysis method.
2. Provide guidance for the selection of appropriate variables for classification analysis.
3. Promote the use of the guidance in the habitat mapping community.

ii. Benefits

- More standardisation in the use of classification analysis among the habitat mapping community, leading to habitat maps being more comparable. This would be a necessary step towards monitoring habitat area change.
- Users are more likely to choose to most appropriate method and variables for classification analysis, leading to higher quality habitat maps.

iii. Products

1. **Name**: literature review examining classification analysis methods for various purposes (this should include terrestrial remote sensing).
   Purpose: to inform the creation of the decision tree and the writing of the ROG.
   Audience: the authors of the ROG (product 3).
   Media: document.
   Potential structure: to be decided, but could include topics such as:
   a. What classification analysis methods are currently in use?
   b. What methods are suitable depending on input variables, data types and seabed types?
   c. What methods are required for different end uses?
   Skill-set requirement: experience carrying out classification analysis using multiple methods, understanding of the various uses of habitat maps, knowledge of terrestrial mapping methods, understanding of the practical limitations and feasibility of various methods regarding data and software availability, and report-writing skills.
   Resource requirement: a very rough estimate is a total of 35 person-days, including carrying out the review (20), writing the report (10), peer-review of report (4), and administration (1).
   Potential producer(s): to be decided, but Cefas, AFBI, NOC and NRW expressed an interest in this at the workshop.

2. **Name**: workshop with experts to help formulate the decision tree for the ROG.
   Purpose: to gain consensus about the decision tree to be contained in the ROG.
   Audience: workshop participants and authors of the ROG.
   Media: workshop.
   Potential structure: to be decided.
   Skill-set requirement: as a whole the workshop participants should possess all of the skills described for product 1. The workshop organisers need an understanding of who possesses these skills and the ability and contacts required to arrange the workshop.
   Resource requirement: perhaps 10 workshop participants for 1-2 days each and 5 person-days for workshop organisation.
   Potential producer(s): to be decided but JNCC are one potential organisation for organising the workshop. Workshop participants are likely to be similar to those who attended this workshop plus terrestrial remote-sensing experts and selected international experts. The producer(s) of product 1 should be involved.

3. **Name**: ROG for classification analysis.
   Purpose: to provide guidance for the selection of appropriate classification analysis method
   Audience: producers of habitat maps.
   Media: document, available online.
   Potential structure:
   a. a decision tree for choosing the best analysis method depending on the habitat, the input data, the purpose (e.g. discovery mapping or monitoring), *etc*;
   b. guidelines on the ensemble approach (Diesing & Stephens 2015) for discovery mapping;
   c. guidelines on the selection of appropriate derived variables and scales, including:
      i. how to choose the appropriate spatial scale(s) at which to calculate the variable;
      ii. how to select the appropriate variables;
      iii. variables derived from backscatter as well as bathymetry;

iv. specifying variables to use for particular habitats.

d. instructions on the need for all habitat maps to be accompanied by some form of quality estimate that states the classification success associated with a map, including:
   i. publication of two or more accuracy measures;
   ii. overall and class-specific measures;
   iii. publication of associated confidence limits;
   iv. provision of an error matrix/contingency table.
e. Instructions to provide detailed information of process and variables within metadata.

Skill-set requirement: as for product 1.
Resource requirement: a very rough estimate is a total of 30 person-days, including writing the various sections (potentially having different organisations leading on different sections) (25), peer-review of the document (4) and administration (1).
Potential producer(s): in general several organisations expressed some interest in being involved while at the workshop: Cefas, MSS, IECS, Envision, EA (geomatics team), BGS, NOC, AFBI, NRW, SAMS, Fugro and JNCC. The producer(s) of product 1 and the organisers of the workshop (product 2) should be involved.

iv. Exclusions

The following objectives and/or products fall outside of the scope of this project:
1. Guidance on the selection of survey methods (see Solution 7)
2. Guidance on the identification of habitats and biotopes from samples (e.g. grab samples, photographic stills and video).

v. Dependencies

Product 3 is dependent on the completion of product 2, which is dependent on the completion of product 1. Product 1 would be of some use as a stand-alone product if further resources are not available. The creation of all products is dependent on the resources available.

vi. Potential source(s) of staff and/or funding

This project is of interest to a wide range of habitat mappers in the UK; it is also assumed that it would be of equal use to habitat mappers in other countries. For this reason, there is potentially the opportunity to fund such work through a European-funded project, or through collaboration with the GeoHab[13] community or the International Council for the Exploration of the Seas (ICES) Working Group on Marine Habitat Mapping. It is also worthwhile mentioning that the three national mapping programmes of the UK (MAREMAP[14]), Ireland (INFOMAR[15]) and Norway (MAREANO[16]) have recently agreed a closer cooperation and set up three task

[13] GeoHab (Marine **Geo**logical and Biological **Hab**itat Mapping) is an international association of marine scientists studying biophysical (i.e., geologic and oceanographic) indicators of benthic habitats and ecosystems as proxies for biological communities and species diversity. See http://geohab.org/.
[14] MAREMAP (Marine Environmental Mapping Programme) is an initiative that brings together Natural Environmental Research Council (NERC) organisations and other associate partners to collaborate on marine mapping projects. See www.maremap.ac.uk/view/information/about.html
[15] INFOMAR (**IN**tegrated Mapping **FO**r the Sustainable Development of Ireland's **MA**rine **R**esource programme) is a joint venture between the Geological Survey of Ireland and the Marine Institute, which concentrates on creating a range of integrated mapping products of the physical, chemical and biological features of the seabed in the near-shore area. See www.infomar.ie/
[16] The MAREANO programme is led by the Institute of Marine Research, the Geological Survey of Norway and the Norwegian Mapping Authority and maps depth and topography, sediment composition, biodiversity, habitats and biotopes as well as pollution in the seabed in Norwegian offshore areas. See www.mareano.no/en/

groups, one of which deals map production and is led by M. Diesing. While this mechanism is unlikely to fund any work, there might nevertheless be synergies.

Interim products 1 and/or 2 may be small enough to achieve on relatively low funding, meaning that it might be possible to fund one or both of these through existing budgets in one or more of the interested organisations. This would need to be discussed with the Seabed Mapping Working Group.

There is a research element to this, especially if a practical comparative study is undertaken, or a study to test the guidance. Therefore it may be possible to obtain funding from the Natural Environment Research Council (NERC) if it were run in conjunction with a university.

4.2.2 Solution 30: ROG on sample distribution

i. Objectives

1. Provide guidance on the placement of replicates within a survey area.
2. Develop spatial statistical tools that can facilitate the placement of replicates in high heterogeneity areas and across boundaries.
3. Promote the use of the guidance and tool in the habitat mapping community.

ii. Benefits

- Surveyors who use the guidance and/or tool would be more likely to distribute their samples to maximise the ability to distinguish between classes and class units and therefore lead to higher quality habitat maps.
- Habitat mappers would be better able to express the suitability of the sample distribution in a consistent way to allow comparison with other maps and to identify areas in need of further survey.

iii. Products

1. **Name**: improvements to the existing Clements *et al* (2010) OAA tool.
   Purpose: to provide guidance on the distribution of samples within a study area for habitat mapping.
   Audience: surveyors and survey planners.
   Media: an online/downloadable tool
   Potential Structure: to be decided, but could include:
   a. adding the ability for nesting to cover units of the same class;
   b. making it easier to use; and
   c. potentially adding some default habitats that can be selected from a list.
   Skill-set requirement: experience planning and conducting seabed sampling, statistics (e.g. power analysis), knowledge of terrestrial sampling strategies and application development.
   Resource requirement: a rough estimate is a total of 13 person-days, including tool development (10) and peer-review (3).
   Potential producer(s): AFBI could take the lead as original developers of the tool, with additional support from elsewhere, potentially including a terrestrial sampling/statistical expert from BGS.

2. **Name**: a review and ROG to cover aspects not covered by the improved tool (product 1).
   Purpose: to provide guidance on the distribution of samples within a study area for habitat mapping, with reference to existing or updated survey planning tools such as the OAA tool.
   Audience: surveyors and survey planners.
   Media: document, available online.
   Potential structure: to be decided, but could include:
   a. the purpose of ground-truthing, i.e. for model training and validation;
   b. the value of stratification;
   c. guidance about statistical and geo-spatial factors that hamper ground-truthing/model training, e.g. spatial autocorrelation;
   d. what can be realistically detected using acoustic datasets,
   e. survey designs (e.g. regular vs. gridded stations, mid-polygon vs. boundary edges *etc*);
   f. how to provide a fuller 'signature' of habitat occupation;
   g. skewing the distribution of samples towards area at risk (within pressure footprint); and
   h. distributing samples according to environmental gradients present within the survey site rather than classes identified by unsupervised classification (e.g. van Son *et al* 2015).

   Skill-set requirement: as for product 1 (minus application development), report-writing.
   Resource requirement: a very rough estimate is a total of 30 person-days, including writing the various sections (potentially having different organisations leading on different sections or groups of sections) (20), peer-review of the document (ideally by a wide-range of institutes) (9) and administration (1).
   Potential producer(s): This could include the producers of product 1, but may be led by another institute or agency.

iv. Exclusions

The following objectives and/or products fall outside of the scope of this project:
1. Guidance on the selection of sampling methods (see Solution 7).
2. Guidance on the number of samples to take during a survey (see Solution 29); although this could possibly be incorporated into the same solution.

v. Dependencies

Product 2 is dependent on the completion of product 1. Product 1 would be of some use as a stand-alone product if further resources are not available. The creation of both products is dependent on the resources available.

vi. Potential source(s) of staff and/or funding

This project is of interest to a wide range of habitat mappers in the UK; it is also assumed that it would be of equal use to habitat mappers in other countries. For this reason, there is potentially the opportunity to fund such work through a European-funded project, or through collaboration with the GeoHab community or the ICES Working Group on Marine Habitat Mapping. As above, one of the three task groups of the MAREMAP-INFOMAR-MAREANO collaboration focuses on sampling design and has involvement from some members of this group. While this mechanism is unlikely to fund any work, there might nevertheless be synergies.

Interim products 1 and/or 2 may be small enough to achieve on relatively low funding, meaning that it might be possible to fund one or both of these through existing budgets in one or more of the interested organisations. This would need to be discussed with the Seabed Mapping Working Group.

4.2.3 Solution 15: ROG for multi-beam echo sounder backscatter collection

i. Objectives

1. Produce guidance on the collection of multi-beam backscatter data that is both fit for various purposes and most likely to be adopted.
2. Discover the feasibility of the hydrographic community and industry adopting the proposed guidance.
3. Promote the use of the guidance in the habitat mapping community.

ii. Benefits

- More standardisation in the collection of backscatter data, leading to habitat maps being more comparable. This is an essential prerequisite for monitoring habitat area change.
- Surveyors are more likely to collect high quality backscatter data, leading to higher quality habitat maps.
- Some guidance already exists (e.g. Lurton & Lamarche 2015); therefore it may not require too much additional effort to distil the information into an easily digestible document that people are more likely to read.
- Better value for money, as the data collected by, e.g. the Civil Hydrography Programme could be used for several purposes, rather than leading to the risk that an area needs to be remapped for backscatter collection.

iii. Products

1. **Name**: review and comparison of existing standards for backscatter data collection, including organisation-specific standards (e.g. Cefas, BGS), INIS HYDRO (2013) and Lurton and Lamarche (2015).
   Purpose: to identify common standards/guidelines and resolve differences in order to select the best guidance to include in a generic guidance document.
   Audience: the authors of the ROG (product 2).
   Media: document.
   Potential structure: to be decided, but could include:
   a. introduction to each of the existing standards/guidelines and a summary of what they do and do not cover;
   b. a comparison between the existing standards/guidelines highlighting similarities and differences;
   c. identification of which existing guidance to include in the ROG;
   d. identification of additional guidance for the ROG that needs to be created.
   Skill-set requirement: experience planning and conducting multi-beam surveys for the collection of backscatter, understanding of the various uses of habitat maps, understanding of the practical limitations and feasibility of various approaches, and report-writing skills.
   Resource requirement: a very rough estimate is a total of 28 person-days, including carrying out the review (20), writing the report (5), peer-review of report (2), and administration (1).
   Potential producer(s): to be decided, but should be coordinated through the Seabed Mapping Working Group, because it is in the group's 15-16 work plan.

2. **Name**: workshop to develop guidance.
   Purpose: to introduce the results of the review of standards/guidelines to the hydrographic community and industry and discuss the contents of a ROG for the collection of multi-beam backscatter data.
   Audience: surveyors and survey planners from the hydrographic community and industry.
   Media: workshop.
   Potential structure: to be decided.
   Skill-set requirement: as a whole the workshop participants should possess all of the skills described for product 1 (minus report-writing). The workshop organisers need an understanding of who possesses these skills and the ability and contacts required to arrange the workshop.
   Resource requirement: perhaps 20 workshop participants for 1-2 days each and 5 person-days for workshop organisation.
   Potential producer(s): to be decided, but should be coordinated through the Seabed Mapping Working Group, because it is in the group's 15-16 work plan.

3. **Name**: ROG for the collection of multi-beam backscatter data.
   Purpose: to provide guidance on the collection of multi-beam backscatter data.
   Audience: surveyors and survey planners.
   Media: document, available online.
   Potential structure: to be decided, but made need to provide different guidelines for monitoring and discovery mapping as the former would need a higher specification.
   Skill-set requirement: as for product 1.
   Resource requirement: a very rough estimate is a total of 15 person-days, including writing the document (10), peer-review of the document (4) and administration (1).
   Potential producer(s): to be decided, but should be coordinated through the Seabed Mapping Working Group, because it is in the group's 15-16 work plan.

iv. Exclusions

The following objectives and/or products fall outside of the scope of this project:
1. Guidance on the selection of survey methods (see Solution 7).
2. Guidance on the standardised processing of multi-beam data (see Solution 17).

v. Dependencies

Products 2 and 3 are dependent on the completion of product 1. Product 3 could be developed without product 2 (the workshop), but the end result may be a lower quality and/or less well adopted. Product 1 would be of some use as a stand-alone product if further resources are not available. The creation of all products is dependent on the resources available.

vi. Potential source(s) of staff and/or funding

This project is of interest to a wide range of seabed mappers in the UK and the funding of the work should be discussed further within the Seabed Mapping Working Group as this is within the group's work plan.

4.3 Solutions not discussed further at the workshop

4.3.1 Solution 7: Optimum selection of mapping methods

Although this solution was not selected for further discussion at the workshop, the participants agreed that this may need to be prioritised as the Suitability Tool is already well developed, containing useful material and was referred to many times throughout the workshop.

Some discussion occurred earlier on in the workshop about resources, which concluded that the end users of maps should be the ones to drive this solution forward, e.g. those responsible for regulation, monitoring and conservation advice.

It was also acknowledged that it would be important to engage with all potential users in UK and in Europe, as well as industry, from the very beginning of the process.

4.3.2 Solution 29: ROG on sample replication

The preferred solution was a guidance document containing rules of thumb and case studies relating to sample replication. The participants identified the Seabed Mapping Working Group and the ICES Working Group on Marine Habitat Mapping as groups to approach to acquire some case studies on the relationship between replication and power/accuracy.

The attendee also identified the Seabed Mapping Working Group as the group to lead the review of case studies and writing of a subsequent guidance document.

It was noted that Natural England have experience of using power analyses to inform replication of samples for habitat mapping and may be able to advise on this.

4.3.3 Solution 17: standardised processing of multi-beam echo sounder data

The participants agreed that a guidance document would be useful, containing a series of generalised case study reports. The participants also agreed that a quality control scheme including a cross-validation/inter-calibration exercise could result in improvements. However, a scheme like this would need a high level driver, such as from the Marine Assessment and Reporting Group, HBDSEG or the Seabed Mapping Working Group.

4.4 General points raised throughout the workshop

There were several general and or recurring points raised throughout the workshop. Here is a summary:

- A recurring message was that the purpose of the mapping should be a factor in determining methods and approaches, i.e. is it so-called “discovery mapping” to find out what is there and its extent or “monitoring mapping”; a repeat survey of a previously mapped area to detect change? It was clarified that the workshop should be focussing on the latter – monitoring habitat extent change.

- However, as the work develops people should keep in mind that many of the issues associated with mapping for monitoring habitat area are also relevant for discovery mapping.

- For monitoring, the amount of change to be detected influences the quality of habitat map that is required. For assessments related to the Habitat Directive, a maximum acceptable amount of area change for habitats listed under Annex I of the directive is 5 %. According to the minimum detectable changes determined in objective 4 of Strong (2015), this could be difficult for some habitats. Under the MSFD, the current targets refer only to direction of change; therefore a range of uncertainty is required for each habitat in order to be able to determine whether a change is likely to have occurred or not.

- There are many lessons that can be learnt from terrestrial earth observation and mapping, and other areas of statistics. We need to make sure we research these areas and consult with experts in these areas to ensure we do not waste time replicating work.

- Whether or not an area is at risk of damage could warrant a lower level of uncertainty, potentially changing the decision about which methods to use.

- Industry needs to be involved in any further work. Current activity noted at the workshop:
  - the oil and gas industry (UK Oil and Gas) has commissioned the University of Hull to write four standardised seabed strategies to enable them to meet regulations and gather best quality data;
  - the aggregate industry (British Marine Aggregate Producers Association) is also looking at efficiency gains in data collection from survey;
  - the renewables industry is beginning to consider monitoring approaches and may appreciate guidance documents such as the ones discussed at the workshop.

- Where should new guidance be published? There are many websites where guidance related to seabed survey, monitoring and/or mapping can be found, e.g. the JNCC Marine Monitoring Handbook (MMH) (Davies *et al* 2001) and MESH ROGs. They are usually hosted on the website associated with the particular funding organisation or project. To address the issue of these documents being spread out across multiple websites, JNCC have recently developed the Marine Monitoring Method Finder – an online portal containing links to all ROGs, SOPs and tools for marine monitoring methods[17]. If there is no other logical place for hosting new ROGs or SOPs, for example, any created as a result of this workshop, they may be hosted here. It was suggested at the workshop that the portal could include a quality control element whereby certain ROGs, SOPs and tools are accredited to give an indication of quality, relevance and/or importance.

[17] UK Marine Monitoring Method Finder: http://jncc.defra.gov.uk/page-7171.

5 Next Steps and Conclusions

This report highlights the priorities for marine habitat mapping standardisation in the UK, as agreed by a range of practitioners and users of habitat maps. This work is essential if the UK is to be able to accurately monitor habitat area change in habitats at risk from human activities in the future.

The next step is to communicate further with organisations that have the skill-sets, resources and/or internal requirements in order to gain commitments on staff time and/or funds towards achieving one or more of the products identified in Section 4.2.

The Seabed Mapping Working Group will be the conduit for these further discussions and the work to be done will be incorporated into the group's work plan. The group chair's responsibility in this regard is not to manage or lead any of the work, but to:

- Maintain an oversight of the relevant activities occurring around the UK.
- Assess the progress of achieving the objectives on an annual basis and report back to the group.
- Encourage group members to take on and/or fund tasks related to this work, individually or through collaboration with other organisations.
- Look out for and notify the group of any potential funding streams and/or unrealised linkages to be made between current and future projects.

There may be cases where group members become involved in related work either independently or in response to the requirements described in this report. Group members should be encouraged to notify the group chair of any potentially relevant work that is happening, who can then record these against the relevant objectives in the work plan. It is recognised that there is potential for long timescales associated with the development of work if funding is not identified and priorities should be reviewed periodically.

Most of the issues discussed at the workshop are not specific to the UK and other countries may be interested in the development of some of the solutions. Therefore an important conduit for similar discussions at an international level is the ICES Working Group of Marine Habitat Mapping, through which additional collaborations and funding opportunities could be identified. Additionally, aspects of sampling design and map production will be addressed by task forces under the newly established collaboration between the MAREMAP, INFOMAR and MAREANO national mapping programmes.

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Appendix 1: Habitats for which a Habitat Area-Based Indicator may be Appropriate

The habitats listed below are those identified following the March 2013 workshop described in Frost *et al* (2013) as most suitable for assessment of habitat area as an indicator of environmental status under the MSFD.

Atlantic salt meadows (*Glauco-puccinellietalia maritimae*)
Coastal (saline) lagoons
Coastal saltmarsh
Cold water coral reefs (*Lophelia pertusa* reefs)
Estuaries
Estuarine rocky habitats
File/flame shell beds (*Limaria hians*)
Fragile sponge and anthozoan communities on subtidal rocky habitats including northern sea fan and sponge communities
Intertidal chalk and associated communities
Intertidal *Mytilus edulis* beds on mixed and sandy sediments
Mudflats and sandflats not covered by seawater at low tide
Kelp and seaweed communities on sublittoral sediment
Large shallow inlets and bays
Maerl beds
Modiolus modiolus beds
Mytilus edulis beds
Ostrea edulis beds
Salicornia and other annuals colonising mud and sand
Seagrass beds/*Zostera* beds
Sea pen and burrowing megafauna communities/burrowed mud
Serpula vermicularis reefs
Spartina swards (*Spartinion maritimae*)
Submarine structures made by leaking gases (to include “bubbling reefs” and “pockmarks” made up of carbonate structures)
Sheltered muddy gravels
Moderate energy intertidal rock
Low energy intertidal rock

Appendix 2: Workshop Participant List

No	Name	Organisation	Position/Role in the workshop
1	Helen Lillis	Joint Nature Conservation Committee	Marine Mapping Manager/Organiser
2	Beth Stoker	Joint Nature Conservation Committee	Marine Evidence Team Leader/Chair
3	Abigayil Blandon	Joint Nature Conservation Committee	MSFD Benthic Habitats Advisor/Note-taker
4	Joey O'Connor	Joint Nature Conservation Committee	Seabed Survey Scientist/Group facilitator
5	Henk van Rein	Joint Nature Conservation Committee	Marine Monitoring Ecologist
6	Rebecca Lowe	Defra	Marine Biodiversity R&D Programme Manager
7	Koen Vanstaen	Centre for Environment, Fisheries and Aquaculture Science	Group Manager – Evidence and Interpretation/Chair of SBMWG
8	Markus Diesing	Centre for Environment, Fisheries and Aquaculture Science	Senior Geoscientist/Group facilitator
9	James Strong	Institute of Estuarine and Coastal Studies, University of Hull	Senior Benthic Ecologist and Seabed Surveyor/Group facilitator/Chair of ICES Working Group on Marine Habitat Mapping
10	Sophie Green	British Geological Survey	Marine Geoscientist/Group facilitator
11	John Baxter	Scottish Natural Heritage	Principal Adviser Marine
12	Karen Robinson	Natural Resources Wales	Marine Ecologist
13	Dave Tavner	Natural Resources Wales	Marine Mapping Scientist
14	Peter Walker	Natural England	Lead Adviser: Marine Data Management and Geographic Information
15	Ian Saunders	Natural England	Senior Adviser: Marine Data Management and Geographic Information
16	Nuala McQuaid	Department of Environment Northern Ireland	Marine Conservation and Data Reporting
17	Matthew Service	Agri-Food and Biosciences Institute Northern Ireland	Programme Leader Coastal Science
18	Rebecca Taylor	Marine Management Organisation	Senior Evidence Specialist
19	Marion Harrald	Marine Scotland Science	Seabed Habitat Interpreter
20	Graham Phillips	Environment Agency	Marine Technical Specialist
21	Keith McGruer	Environment Agency	Marine Technical Officer
22	Katleen Robert	National Oceanography Centre Southampton	Post-Doctoral Research Assistant
23	Ian Sotheran	Envision	Director
24	Tom Wilding	Scottish Association of Marine Sciences	Benthic Ecologist
25	Richard Walters	Fugro	Ecology Dept Manager
26	Andrew Griffith	Fugro	Marine Ecologist
27	Roger Coggan	Independent	Marine Biologist

Appendix 3: Workshop Programme

Day 1	
09:00 – 09:30	**Arrival for a 09:30 start – with Tea/Coffee**
09:30 – 10:30	**SESSION 1: overview presentations** **Introduction:** Welcome (Beth Stoker, JNCC) Workshop background, aims and objectives (Helen Lillis, JNCC) **Key outcomes of Defra project ME5318 (objectives 1-3) – MSFD indicators of habitat extent: the identification of suitable and sensitive habitat mapping methods for specific habitats with recommendations on best-practice for the reduction of uncertainty** (James Strong, IECS)
10:30 - 10:45	**Break**
10:45 – 12:00 **10:45 – 11:00** **11:00 – 11:45** **11:45 – 12:00**	**SESSION 2: developing the uncertainty reduction solutions identified in ME5318** **Introduction to the breakout session** (Helen Lillis, JNCC) **Introduction to the topics for discussion:** **1. Survey planning** (James Strong, IECS) **2. Backscatter collection, processing and interpretation** (Sophie Green, BGS) **3. Habitat map creation** (Markus Diesing, Cefas) **Which other uncertainty reductions solutions are important to prioritise for you/your organisation and what can be done?** *(Post-it exercise).*
12:00 – 13:00	**LUNCH**
13:00 – 14:00	**Carousel brainstorming exercise: developing the uncertainty reduction solutions identified in Strong (2015) with a focus on those associated with survey planning, backscatter and habitat map creation – round 1**
14:00 – 14:15	**Break with Tea/Coffee**
14:15 – 15:00	**Carousel brainstorming exercise continued – round 2**
15:00 – 15:15	**Break**
15:15 – 16:00	**Carousel brainstorming exercise continued – round 3**

DAY 2	
09:00 – 09:15	**Arrival for a 09:15 start**
09:15 – 10:30 **09:15 – 10:15** **10:15 – 10:30**	**SESSION 3: next steps** **Outcomes of session 2 group discussions** **1. Survey planning** (James Strong, IECS and Joey O'Connor, JNCC) **2. Backscatter collection, processing and interpretation** (Sophie Green, BGS) **3. Habitat map creation** (Markus Diesing, Cefas) **Which other uncertainty reductions solutions are important to prioritise and what can be done?** Summary of yesterday's post-it notes.
10:30 – 11:00	**Tea/Coffee**
11:00 – 12:30	**Turning the discussion outcomes into a plan of action** (Koen Vanstaen, Cefas, SBMWG chair)
12:30 – 13:30	**LUNCH**

Appendix 4: Importance of other URSs

Table 2: results from the exercise in Session 2 for participants to express opinions on the relative importance of the URSs not discussed in the breakout sessions. Note that Performance and Cost Effectiveness Ranks from Strong (2015) are out of 39 – the total number of URSs – and the Rank based on stickers is out of 31 – the number of URSs considered in this exercise.

From report (Strong 2015)					From workshop				
Solution number	**Solution status**	**Solution name**	**Perfor-mance rank**	**Cost-effect-iveness rank**	**No. of green stickers**	**No. of red stickers**	**No. green minus no. red stickers**	**Rank based on stickers**	**Workshop comments**
19	existing	MESH and MMH ROGs for benthic sampling	20 / 39	11 / 39	8	0	8	1 / 31	
3	new	Habitat and gap resolution catalogue	2 / 39	20 / 39	7	0	7	2 / 31	
32	new	New NMBAQC epibiota scheme component	5 / 39	19 / 39	8	1	7	2 / 31	1. For monitoring needs to lead to a pass/fail standard. 2. Very important for consistency across contractors in industry. Could go further to implement NMBAQC scheme for review of overall maps.
35	update-able	Guidance on the collection of stills photography	39 / 39	21 / 39	7	0	7	2 / 31	1. Might be a minimum to reach a species discovery threshold rather than a specific number, n >=5. 2. Post-survey selection of images.
25	existing	Guidance on scales and scaling within video and stills samples	13 / 39	18 / 39	6	0	6	5 / 31	1. JNCC guidance on video collection [Hitchin *et al* 2015] now incorporates this. 2. Include distribution of training videos to help consistency of analysts. Rohan Holt has some excellent examples.
33	new	Quantitative definition of EUNIS habitats[18] using common survey variables	17 / 39	32 / 39	7	1	6	5 / 31	A requirement for this in industry as different contractors can work to different classifications or make up their own.

[18] EUNIS habitats: habitats classified according to the marine EUNIS habitat classification system (Davies & Moss 2004)

From report (Strong 2015)					From workshop				
Solution number	**Solution status**	**Solution name**	**Perfor-mance rank**	**Cost-effect-iveness rank**	**No. of green stickers**	**No. of red stickers**	**No. green minus no. red stickers**	**Rank based on stickers**	**Workshop comments**
37	existing	Guidance on the sampling volume of benthic grabs and corers	25 / 39	3 / 39	6	0	6	5 / 31	This should include minimum sample volumes for [particle size analysis] dependent on maximum grain size in sample (representativeness).
28	existing	Guidance on the placement, replication and length of transect sampling	12 / 39	17 / 39	5	0	5	8 / 31	Needs to include a factor considering degree of heterogeneity in a survey area.
22	existing	The selection of video platforms with consistent and controllable survey speeds	16 / 39	2 / 39	4	0	4	9 / 31	1. State when survey technique is not suitable, e.g. in highly turbid environments. 2. Impractical in places such as highly tide-swept areas? 3. Cost is higher if new equipment required?
20	existing	Compensating or substituting platforms with variable fields of view	21 / 39	23 / 39	3	0	3	10 / 31	worthwhile checking outputs from ICES [working group on *Nephrops* surveys].
4	update-able	Positional uncertainty ROG	3 / 39	4 / 39	6	4	2	11 / 31	1. For monitoring repeatability should be considered. 2. Industry already good at positioning accuracy - could potentially assist in leading this discussion (Fugro). 3. Just needs setting of minimum requirement, e.g. dGPS [differential global positioning system] - not SOP or reporting of certainty.
23	new	Guidance on the areal alignment of remotely-sensed and ground-truthing sampling resolutions	22 / 39	34 / 39	4	2	2	11 / 31	Maybe just accept this as a limitation of survey technique.

From report (Strong 2015)					From workshop				
Solution number	**Solution status**	**Solution name**	**Perfor-mance rank**	**Cost-effect-iveness rank**	**No. of green stickers**	**No. of red stickers**	**No. green minus no. red stickers**	**Rank based on stickers**	**Workshop comments**
31	new	SOP/QA (Quality Assurance) for the manual logging of positions or other data	27 / 39	12 / 39	4	2	2	11 / 31	1. Does this need a SOP? Isn't this common sense? 2. Agree with point 1. 3. Minimising transcription minimises error but does not resolve original recording error. Use double independent entry with subsequent plotting. 4. Should be a QA/QC already. 5. Manual logging should be replaced with automated logging. 6. Suggest accreditation for ISO 17025 may help to audit this concern (industry).
5	new	Updated MESH ROG (airborne digital imagery) with methods/SOP for radiometric, atmospheric and geometric correction for marine satellite/aerial surveys	14 / 39	28 / 39	1	0	1	14 / 31	
13	existing	MMH/MESH ROGs covering track spacing and semivariogram analysis use	18 / 39	39 / 39	4	3	1	14 / 31	1. Too many issues compounded in line spacing - is it single-beam or multi-beam echo sounder? 2. [Acoustic ground discrimination systems are] (nearly) redundant for monitoring purposes - too highly variable over time. 3. All [multi-beam echo sounder surveys] should be 100% cover - use block surveys rather than zero overlap (open design) surveys. 4. Strongly agree with points 2 and 3 (MD).
24	existing	Guidance on optimizing visibility within footage	35 / 39	16 / 39	2	1	1	14 / 31	New JNCC video guidance (Hitchin *et al* 2015] may help here.
2	update-able	MESH airborne digital imagery ROG and	31 / 39	27 / 39	2	2	0	17 / 31	

From report (Strong 2015)					From workshop				
Solution number	**Solution status**	**Solution name**	**Perfor-mance rank**	**Cost-effect-iveness rank**	**No. of green stickers**	**No. of red stickers**	**No. green minus no. red stickers**	**Rank based on stickers**	**Workshop comments**
		wavelength/habitat catalogue							
6	new	ROGs for the choose and integration of ancillary data with aerial imagery	15 / 39	33 / 39	0	0	0	17 / 31	
10	update-able	Updated MESHAtlantic LiDAR ROGs with processing SOP	28 / 39	36 / 39	1	1	0	17 / 31	
21	existing	Guidance on the selection of methods with adjustable viewing angles (tilt) for rugged habitats	24 / 39	35 / 39	1	1	0	17 / 31	
27	existing	Guidance on the design of diver surveys	11 / 39	24 / 39	1	1	0	17 / 31	Too many spatial variables for this to work, short of strapping an [ultra-short baseline positioning system] to a diver.
9	new	Projections and datum ROG	30 / 39	14 / 39	1	2	-1	22 / 31	1. There seem to be a few solutions around positioning - COMBINE ALL IN ONE, e.g. Tables 71, 49, 44 [in Strong (2015), solutions 31, 9, 4] 2. MESH formats already define projection required, just needed to standardise transformations. 3. Transformations of projections should be considered. 4. Clarify whether data acquisition or data processing. 5. This should be a standard not a ROG.
14	existing	Guidance and standards for bathymetric data quality	36 / 39	5 / 39	2	4	-2	23 / 31	

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16	existing	Guidance and standards for bathymetric sounding density	19 / 39	2 / 39	0	2	-2	23 / 31	
39	existing	Guidance on the design of field surveys and reduction of environmental artefacts in data	38 / 39	7 / 39	1	3	-2	23 / 31	
38	existing	Quality assurance for benthic sample processing	34 / 39	38 / 39	0	3	-3	26 / 31	Mesh size?
12	existing	MMH and MESH survey ROGs for AGDS (Acoustic Ground Discrimination System) covering survey speeds	32 / 39	37 / 39	1	5	-4	27 / 31	AGDS not suitable for monitoring.
26	update-able	Guidance on the storage of video footage and photographic stills	33 / 39	15 / 39	2	6	-4	27 / 31	Align with MEDIN.
1	existing	MMH and MESH ROGs for AGDS	37 / 39	6 / 39	0	5	-5	29 / 31	
36	new	Guidance on the use of GPS for intertidal mapping	26 / 39	10 / 39	1	6	-5	29 / 31	Should be a standard not a ROG. Too much variability in manufacturers to cover all bases.
11	update-able	AGDS ROG module covering frequency selection	29 / 39	13 / 39	0	8	-8	31 / 31	