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Dear Kay, K-J

Please find attached the fifth instalment of documents.

Best regards,

Dr Dominika Chalder PIEMA
Environment and Consent Manager

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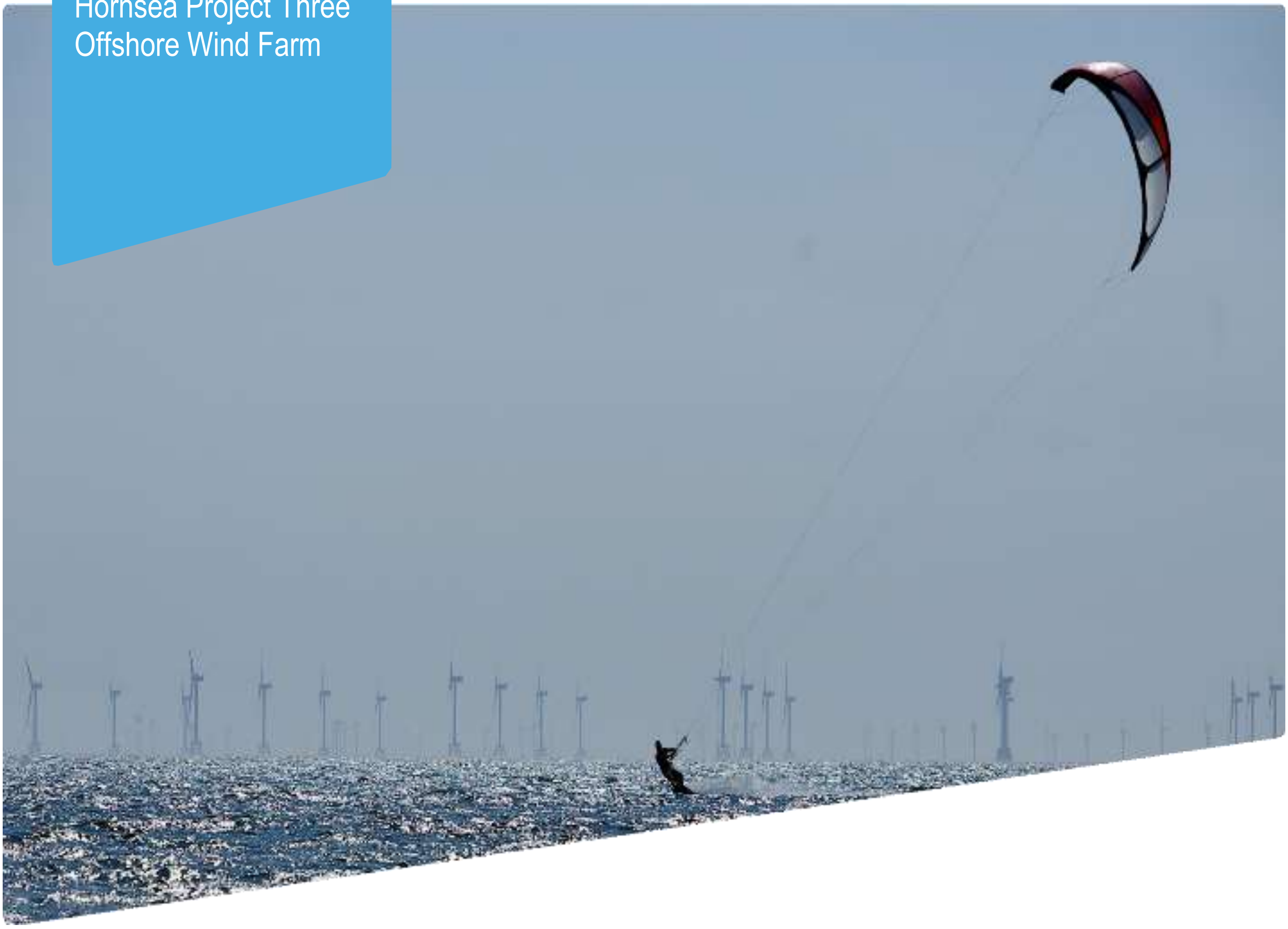

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Offshore Wind Farm

Appendix 8 to Deadline 3 Submission – – Ware, S.J. & Kenny, A.J. 2011

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Hornsea 3
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Aggregate Levy
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MALSF

Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites

2nd Edition

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Client contact details

MEPF-MALSF
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NR33 0HT

Background to the MALSF

In 2002 the Government imposed a levy on all primary aggregates production (including marine aggregates) to reflect the environmental costs of winning these materials. A proportion of the revenue generated was used to provide a source of funding for research aimed at minimising the effects of aggregate production. This fund, delivered through Defra, is known as the Aggregate Levy Sustainability Fund (ALSF); **marine** is one element of the fund.

Further information on the ALSF is available at http://alsf.defra.gov.uk/

Governance

The Defra-chaired MALSF Steering Group develops the commissioning strategy and oversees the delivery arrangements of the MALSF.

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Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites

2nd Edition

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JNCC Joint Nature Conservation Committee

Foreword

In 2002, guidelines were published by the Department for Transport, Local Government and Regions (DTLR) on best practice conduct of benthic ecological studies at marine aggregate (sand and gravel) dredging sites. The original guidelines are now almost a decade old and as our understanding of impacts associated with the extraction of aggregate resources from the seabed has improved, together with technological advances in survey equipment, these updated guidelines capture our present understanding of best practice in undertaking benthic ecological surveys around British coastal waters.

Marine dredged sand and gravel make an important contribution to regional supplies of primary aggregate used in the construction industry and are also a key resource in supporting the delivery of major infrastructure projects that support Government policies related to ensuring energy security and combating climate change. For example, marine dredged aggregate is likely to play a key role in any future port, nuclear and offshore wind farm developments in addition to ongoing beach replenishment and flood defence works. This document provides guidance on establishing robust assessment and monitoring programmes to detect impacts outside of areas licensed for aggregate extraction and will help to ensure impacts to other sea uses and receptors are minimised and thus contribute to our vision of sustainable use of our seas.

There is an ever increasing pressure for space in our coastal waters owing to the many competing interests. The Marine Management Organisation (MMO) was established in April 2010 as the Government's champion of sustainable development in the marine and coastal area. A key part of this role is the development of a marine planning system to bring together the environmental, social and economic needs of our seas. Marine plans will ultimately guide both marine users and decision-makers on what activities can be carried out in certain locations and may also indicate the restrictions or conditions that are likely to be imposed as licence conditions.

Whilst these guidelines provide useful generic advice as to the conduct of benthic studies at marine aggregate extraction sites, differences will exist between cases. This guidance is not statutory nor is it meant to replace careful consideration of robust survey design that may need to be developed for individual areas. **We emphasise that this document is only intended for guidance, is not a regulatory instrument and is not a substitute for appropriate consultation with regulators, their advisors or other interested stakeholders.** The MMO is, however, an enabled regulator keen to engage with the marine sector and should be consulted in the first instance for site or case specific advice.

Many organisations and marine scientists have contributed to these updated guidelines and we would like to thank them for their support in the production of this document. The Marine Aggregate Levy Sustainability Fund Steering Group in particular has given time and energy which is gratefully appreciated.

MMO, March 2011

marine management organisation

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These guidelines have been produced as a project funded through the Marine Environment Protection Fund (MEPF) element of the Aggregate Levy Sustainability Fund (ALSF) and have not been subject to formal stakeholder consultation in the same way as formal guidance would be. However, comments and feedback from members of the regulatory community, industry and practitioners in the field have been considered in their development.

- British Marine Aggregate Producers Association (BMAPA)
- AFBI Northern Ireland
- Cefas Regulatory Assessments Team
- Cefas Programme Management Group
- Countryside Council for Wales
- Emu Ltd
- English Heritage
- Envision Ltd
- ERM Ltd
- Institute for Estuarine Coastal Studies (IECS)
- Joint Nature Conservation Committee (JNCC)
- Natural England
- Marine Aggregate Levy Sustainability Fund Steering Group
- Marine Management Organisation (MMO)
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The MEPF and the project team would like to thank all those who have contributed in developing this guidance including participants of the project workshop.

Where no image and figure credits are noted, these have been provided by Cefas specifically for this publication.

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Preface

This document is intended to provide guidance on the conduct of benthic surveys in support of applications for a licence to extract minerals (marine aggregate) from the seabed around British coastal waters. It is targeted at a number of potential users, namely, the marine aggregate industry and their consultants along with statutory consultees, scientific advisors to the regulator and wider stakeholders. These guidelines supersede those published in 2002 (DTLR, 2002), but some details present in the original guidance remain valid and reference to the original guidance is occasionally made in the present text. Furthermore, extensive experience has been gained by the industry and their consultants in the conduct of marine aggregate Environmental Impact Assessments (EIAs) since the publication of the last guidelines and this has been used to direct the scope of survey objectives and associated practices as appropriate in the present revised text.

Under the current regulatory regime, the 'Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007', and their procedural guidance Marine Minerals Guidance Note 1 and 2 (MMG 1 and 2): 'Guidance on the Extraction by Dredging of Sand, Gravel and Other Minerals from the English Seabed' and 'The Control of Marine Minerals from the British Seabed', there is a requirement to carry out an Environmental Impact Assessment (EIA). This requirement will continue under the marine licensing system managed by the Marine Management Organisation (MMO) under the Marine and Coastal Access Act 2009 (www.marinemanagement.org.uk).

As part of the EIA, a consideration of the potential ecological impacts of the proposed activity on seafloor substrates and their associated fauna is required. These guidelines provide specific advice on the expected scope and standards of benthic ecological surveys conducted in support of the wider EIA process which ensures compliance against the following three stages of the regulatory and consenting process:

1. The scope and conduct of benthic ecological surveys and desk studies required to inform an EIA submitted in support of a new or renewal licence application.
2. Ongoing operational monitoring surveys and substantive reviews carried out to determine if the extent and intensity of impacts predicted by the EIA are being realised and to assess the effectiveness of any licence specific conditions imposed.
3. Possible post-extraction surveys carried out following the relinquishment of a licence area to establish the nature and rate of faunal recolonisation and restoration.

PART 1

Context

SECTION 1

Intended Use of These Guidelines

These guidelines are intended to highlight current best practice and to describe a framework within which benthic studies at marine aggregate extraction sites are undertaken. As such these guidelines sit outwith any particular regulatory regime, but they provide a framework for assessment which is compatible with marine licensing in British coastal waters. Whilst these guidelines offer a general assessment framework to undertake benthic studies at marine aggregate sites, site specific circumstances need to be considered and advice sought from relevant regulators, their advisors and practitioners in the field.

Whilst the focus of these guidelines is on the design of surveys and collection of new data to support benthic studies, it is recommended that all available evidence is considered and utilised before the requirement for additional field data collection is considered.

SECTION 2

Importance of Environmental Impact Assessments (EIA)

The UK regional seas provide a wealth of natural resources and services that are subject to increasing pressure by a variety of stakeholder and commercial activities (e.g. the oil and gas industry, renewable energy installations, marine aggregate extraction, shipping, commercial fishing and recreation).

In order to sustain the many benefits society obtains from the sea, it is necessary to have effective management plans which can balance the need for marine resource development with the need to protect the environment and biodiversity. The plans therefore require the execution of appropriate ecological assessments to ensure both the short and long-term ecological outcomes arising from a development such as marine aggregate extraction are acceptable to society. Scientifically robust and transparent assessments are vital for improving our understanding and management of human activities impacting the marine environment and to allow the implementation of effective mitigation measures that prevent or minimise any associated adverse effects.

Whilst the focus of these guidelines is directed towards benthic ecological assessments of marine aggregate extraction, they will be relevant to many other sectors (whose activities impact upon the seabed), especially those which require defining appropriate survey design, sampling objectives and the selection of sampling methodologies.

SECTION 3

Regulatory Process

In 2007 the control of marine aggregate dredging under the Government View (GV) procedure was superseded by the publication of 'The Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007'. The Regulations put the consideration of marine minerals dredging applications on a statutory footing for the first time and provide a basis for the control of the extraction of minerals by dredging in British marine waters. More recently, the Marine and Coastal Access Act received Royal assent in November 2009 and secondary legislation was drafted that repeals The EIA and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland). The navigation consent required under Section 34 of the Coast Protection Act 1949 (and licence required under the Food and Environment Protection Act 1985) were replaced from 6 April 2011 and aggregate dredging applications will need to apply for a Marine Licence that will include both environmental and navigational conditions.

The regulations transpose into UK law the requirements of the European Community Directives on the assessment of the effects of certain public and private projects on the environment (the EIA Directive 1), and on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive 2), with respect to the extraction of minerals by marine dredging. Scotland and Wales have introduced equivalent regulations (see Appendix 3).

The Government's policies on marine mineral extraction are set out in MMG 1 meanwhile procedural guidance is set out in MMG 2 (Appendix 3).

Under the current regulations, the formal application process for a marine aggregate dredging permission can be divided into **three key steps**[1] (outlined in Figure 1) namely:

Step 1: Pre-application review and assessment

Benthic characterisation including pre-dredge baseline survey and monitoring plan

Step 2: Ongoing monitoring and assessment

Including substantive reviews

Step 3: Post-Extraction evaluation

End of licence survey to coincide with the final substantive review

This formal application process is also applicable under the marine licensing system managed by the Marine Management Organisation (MMO) under the Marine and Coastal Access Act 2009.

1 The text box colours used to identify the three key steps in the application process (Figure 1) are also used elsewhere in this document for providing specific information on a particular step.

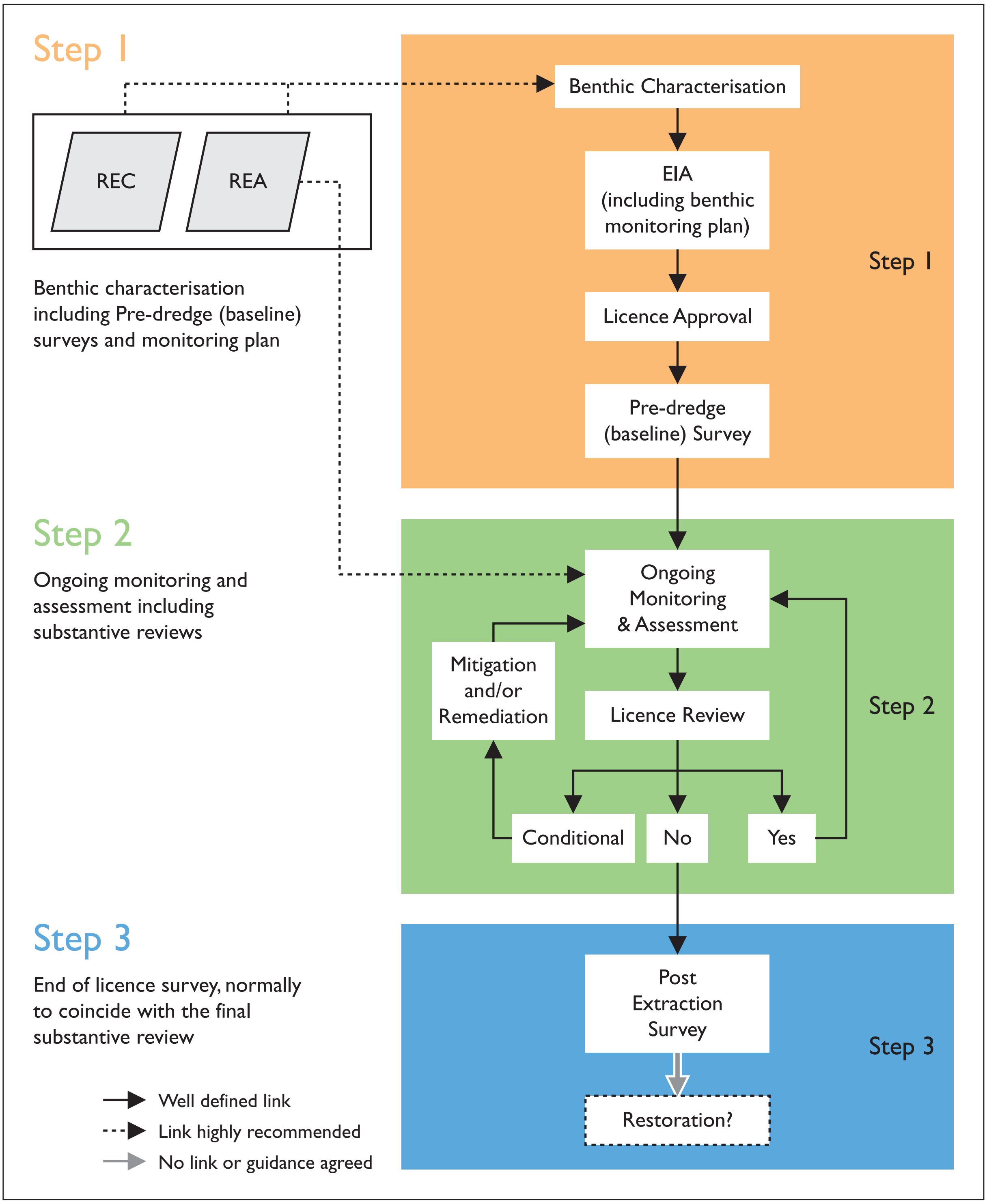


Figure 1. Diagram illustrating the regulatory assessment activities to be implemented (where appropriate) at each step of the regulatory process; coloured steps relate to corresponding sections in this document. Both the REC (Regional Environment Characterisation) and REA (Regional Environmental Assessment) components, where relevant, should be taken into consideration during Steps 1 and 2. For more information on RECs and REAs see page 23.

PART 2

Principles

SECTION 4

Understanding the Dredging Operation and its Effects on the Seabed Environment

This section highlights the most important sources of ecological impact arising from marine aggregate extraction. By having a good understanding of the nature of the dredging operation and the potential sources of impact, the scope of the ecological monitoring and assessment programme can be appropriately defined. The extraction of marine aggregate has its primary impact on the seabed. Assessment of the effects of this dredging has traditionally focused on seabed habitats and their associated fauna (Kenny and Rees, 1994, 1996, Newell *et al.*, 2002, 2004, Boyd and Rees, 2003). However, the secondary impacts, the so called 'indirect impacts' may also be significant (Newell *et al.*, 2002, Desprez *et al.*, 2010), these being primarily caused by the transport of remobilised sediments at the seabed and in the passive sediment plume in the water column (Figure 2).

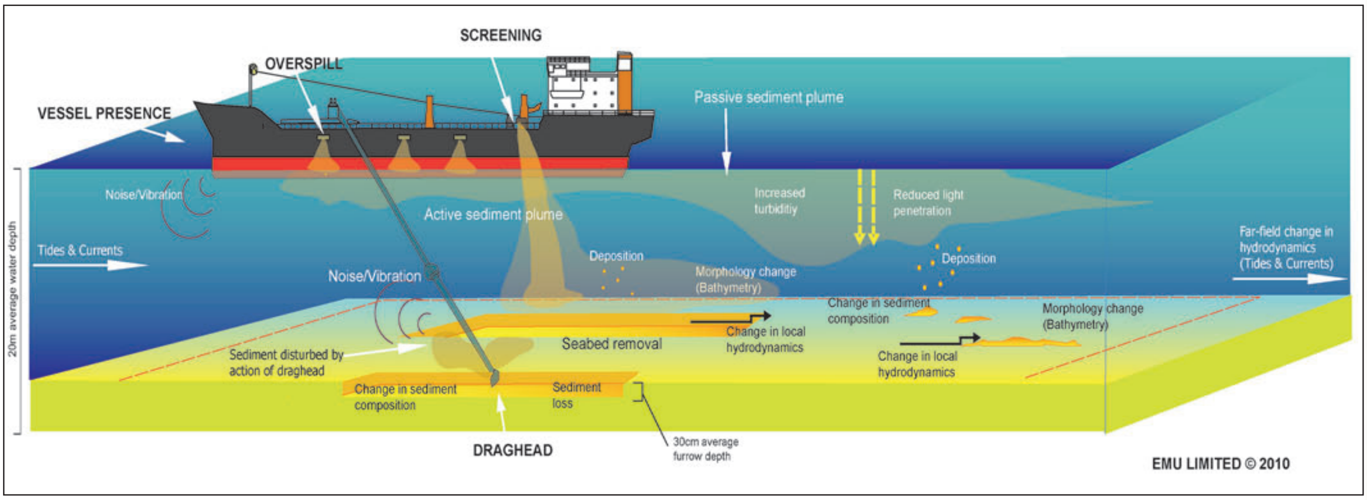


Figure 2. Illustration of the primary and secondary impacts associated with marine aggregate extraction (Copyright Emu Ltd).

The primary impacts are associated with the direct removal of seabed sediments and their associated fauna, the re-suspension of fine sediment and the physical displacement of sediment by the draghead. These impacts are often very localised and confined to the immediate vicinity of the dredging operation; therefore they tend to be observed within certain locations of the licensed extraction area. Secondary impacts arise mainly from the surface discharge of inorganic and organic particulate matter (sediment) from the scuppers and screening chutes of the dredger. Given the main source of the discharge is at the sea surface, there is potential for this material to be dispersed some distance before it reaches the seabed. Under strong currents with extensive tidal excursions, material may impact (negatively or positively) the seabed well outside the boundary of the extraction site.

4.1 Assessing the Receiving Environment

The animals and plants which live on or near the seabed (the benthic assemblages) are an obvious target for the investigations of the ecological effects of marine aggregate extraction because:

- They are consistent features of the seabed environment and vary predictably in association with the physical habitat and in response to anthropogenic impacts.
- Unlike populations of plankton or many demersal fish species, adults of most benthic invertebrates are either sessile or have limited spatial ranges. Thus they are good indicators of locally induced environmental change.
- They may be valued in terms of their links with other resources (e.g. as a food source for commercially exploited fish) as well as containing representatives which are themselves commercially harvested (e.g. crabs, shrimps and mussels).
- They also play a vital role in contributing to the function of marine ecosystems, through the recycling nutrients and energy which helps to maintain the provision of vital ecosystem goods and services.




In the context of benthic surveys conducted to inform the three steps of the regulatory process (see Figure 1) guidance on which attributes of the benthic ecosystem to evaluate can be found in the 'Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007', and their procedural guidance MMG 1 and 2.

The important benthic attributes to assess are given as:

- Bathymetry
- Seabed sediment composition
- Benthos (macrobenthic invertebrates)
- Sensitive species and habitats of conservation importance
- Demersal fish and fisheries
- Location of wrecks or other remains of archaeological interest
- Oceanography (seabed currents caused by tides and waves)[2]

2 Oceanography is not specifically mentioned as one of the important benthic attributes to assess in the 'Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) Regulations 2007', and their procedural guidance MMG 1 and 2. However, it is important that this is assessed to understand causes and pathways of ecological change.

This guidance focuses on the requirements of surveys carried out to evaluate the two benthic components; namely, **seabed sediment composition** and **benthos (macrobenthic invertebrates)**. Additional guidance on the monitoring of sensitive habitats and species can be found in JNCC (2001, 2009) and Limpenny *et al.* (2010), and for archaeological features in BMAPA and English Heritage (2003). However, it should be noted that in order to characterise the seafloor habitats and their associated faunal communities (and to predict the likely extent and significance of impacts) additional information (e.g. local oceanography and hydrodynamics) must also be considered as part of the assessment.

The essential information requirements to assess the status of the seabed habitats and benthos are given below.

4.2 Description of the Physical Nature of the Seabed

The information required to predict the likely zone of impact (including both the primary and secondary sources of impact) arising from the proposed activity should include:

- Assessment of the hydrodynamics of the general area including tidal regime, wave conditions and residual water movements.
- Notable features on the seabed and indicators of tidal current strength and direction should be identified (e.g. orientation of bedforms).
- Assessment of the mobility of the seabed and sediment transport pathways should be based either on direct observations, numerical modelling or inferred from bedform asymmetry and morphology.
- The characteristics of seabed sediments in and around the site should be quantified and described ideally using a combination of side scan sonar, shallow seismic and grab sample data.
- The mineral resource characteristics including particle size and lithology, origin and composition, thickness and nature of underlying deposits should be quantified and described.

4.2.1 Primary (Direct) and Secondary (Indirect) Effects of Aggregate Dredging on Seafloor Sediments (see Figure 3)

- Primary (or Direct) impacts are associated with the direct removal of material from the seabed. This can give rise to changes in the composition of the seafloor sediment and the nature and scale of the seabed topography (e.g. ridges and furrows).
- Secondary (or Indirect) impacts are associated with production of a sediment plume (from the draghead at the seabed, from the hopper overflow, and possibly onboard screening) and its subsequent transportation in the water column or near the seabed as bedload transport. This should be considered together with the background suspended load.

4.3 Description of the Biological Nature of the Seabed

The information required to describe the biology of the area should include:

- A summary of the techniques used and details of all species identified, including their abundance at each sampling station should be recorded as a minimum.
- A description of the benthic communities present within and adjacent to the application area. This should include evaluation of the typical assemblages of species, covering biodiversity, abundance, extent, species richness, representativeness, naturalness, rarity and fragility in and around the proposed dredging area.
- An indication of the sensitivities of particular habitats and species, for example *Sabellaria spinulosa* reefs, or *Modiolus modiolus* beds.
- An assessment of known predator-prey relationships and measures of abundance of dominant species likely to be influenced by aggregate dredging, including temporal and spatial population dynamics of the benthic assemblages.

This information will subsequently be utilised in informing and validating predictions made regarding effects on seafloor sediments and biological impacts.

4.3.1 Primary (Direct) and Secondary (Indirect) Biological Impacts (see Figure 3)

- The principal biological impacts of dredging are the direct removal of benthic organisms, their burial due to re-deposition of sediments and alteration of the seabed topography upon which colonisation and feeding activity depends.
- Dredging should, therefore, "aim to leave the seabed in a similar physical condition to that present before dredging commenced", in order to enhance the likelihood of and the rate at which the seabed recovers physically and biologically to its pre-dredge condition (MMG 1).
- A comprehensive evaluation of the variability of benthic species and communities over space and time will therefore allow a robust and accurate prediction of the likely rate of recovery following the cessation of dredging as part of the EIA.

SECTION 5

Framework for Appropriate Design and Planning of Surveys

The starting point for any survey design is to define the questions which need to be addressed. This is done through a process of defining appropriate impact hypotheses and survey objectives.

5.1 Defining Impact Hypotheses

The primary aim of establishing impact hypotheses is to help define what sampling is needed (i.e. the data and evidence required) to answer specific questions related to quantifying possible changes in the status of the benthic communities as a result of marine aggregate dredging. Impact hypotheses, by definition, are associated with assessing differences between sets of samples, which in turn are associated with different sets of conditions or treatments. In the case of marine aggregate extraction, the treatments (or sets of samples) relate to gradients of change which can be attributed to the direct and indirect effects of dredging (Figures 2 and 3). Although it is recognised that such gradients are continuous (i.e. not discrete), for the purpose of marine aggregate benthic assessments, three categories of condition are defined:

- Primary (or Direct) Impact
- Secondary (or Indirect) Impact
- Reference condition

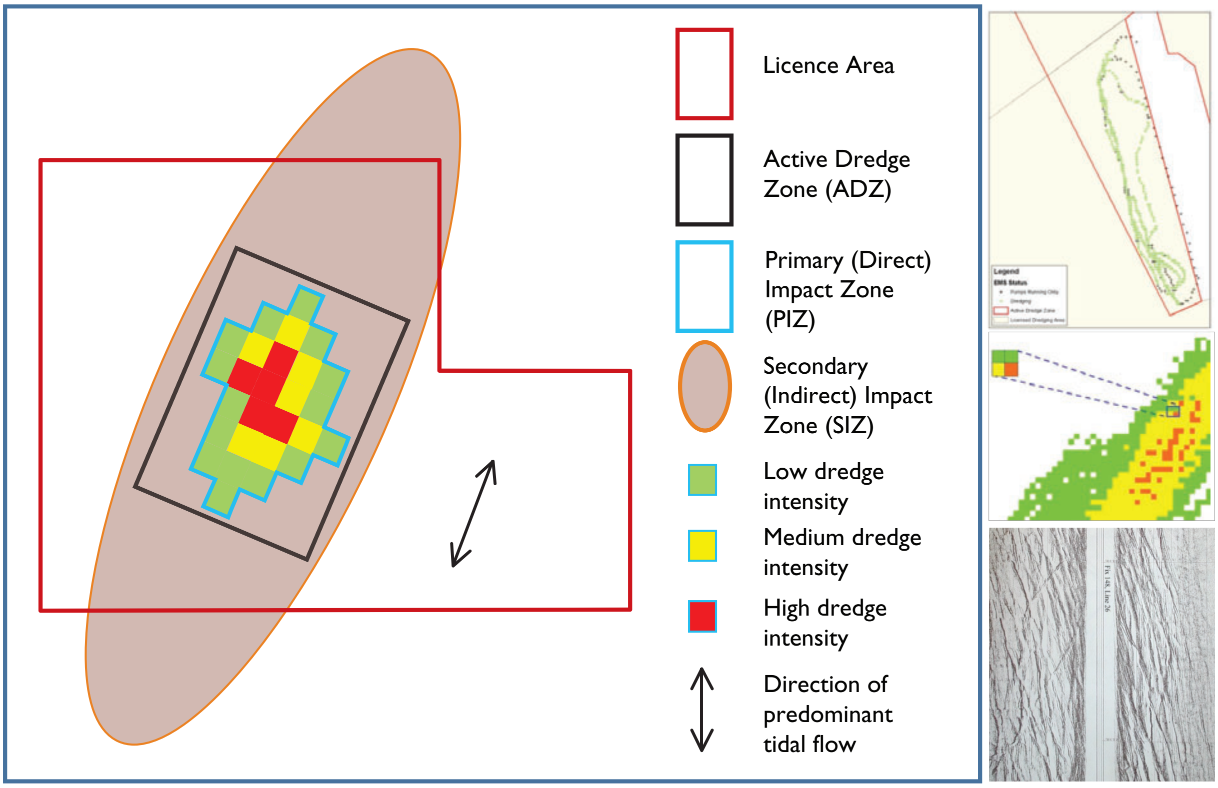


Figure 3. Hypothetical marine aggregate licence area showing Active Dredge Zone (ADZ) (indicated in black), Primary (or Direct) Impact Zone (PIZ) and Secondary (or Indirect) Impact Zone (SIZ). Areas outside the PIZ and SIZ represent potential Reference conditions. The location and spatial extent of the PIZ may be determined using a number of techniques illustrated in the three panels to the right of the figure. These include vessel position fixed every 30 seconds during dredging from Electronic Monitoring System (EMS) records (top panel), EMS intensity analysis (middle panel) and sidescan images of dredged area (bottom panel). Images kindly provided by BMAPA.

Impact hypotheses are therefore associated with quantifying specific differences between these principal areas (or sets of treatments) in both space and time. For example:

For the same biotope, are the type and number of species which occur within the PIZ, the same as those found in the SIZ pre- and post-extraction?

Clearly associated with such hypotheses are a number of conditions (or factors) which must be controlled so as to be certain of the cause of change. These conditions should, where possible, be controlled by defining appropriate survey and assessment objectives which are described in more detail in Section 5.2.

5.2 Survey and Assessment Objectives

Establishing clear survey and assessment objectives from the outset provides the necessary focus for the impact hypotheses and work to be undertaken over the lifetime of the licence. This should be one of the first tasks undertaken, as it guides all subsequent surveys, monitoring and assessment activities. The survey and assessment objectives provide the means of meeting both the requirements of the regulatory process (see Figure 1) and the impact hypothesis framework as defined in Section 5.1.

STEP 1: Pre-application Review and Assessment

Objectives: Site Characterisation including Pre-Dredge (Baseline) Survey and Monitoring Plan

Pre-application (New Licence Application)

- Provide a **spatial description** of the seabed environment within and around the expected impact zones (PIZ and SIZ) including the **identification of important/sensitive habitats and species** (e.g. via suitable single sample station survey design).
- Identify and describe the **spatial extent** and **magnitude** of the possible primary and secondary **impact zones** predicted in relation to the proposed dredging activity and the sensitivity of the seabed environment (e.g. via appropriate stratified random sampling design); and to provide the necessary evidence to assess the nature of possible changes attributable to dredging. Assess whether the predicted impacts are acceptable.

Pre-application (Licence Renewal)

- Provide a **spatial description** of the seabed environment within and around the expected impact zones (PIZ and SIZ) including the **identification of important/sensitive habitats and species** (e.g. via suitable single sample station survey design).
- Identify and describe the **actual spatial extent and magnitude of primary and secondary impacts** resulting from **previous dredging activities** and to assess how such impacts may have contributed to the current environmental status.
- Identify and describe the **spatial extent** and **magnitude** of the possible primary and secondary **impact zones** predicted in relation to the proposed dredging activity and the sensitivity of the seabed environment (e.g. via appropriate stratified random sampling design); and to provide the necessary evidence to assess the nature of possible changes attributable to dredging. Assess whether the predicted impacts are acceptable.
- Provide evidence of the **nature and rate of recolonisation by benthic invertebrates** following cessation of dredging (e.g. via reporting on sites within the licence which have not been dredged for several years).

STEP 2: Ongoing monitoring, assessment and review

Objectives: Ongoing Monitoring and Assessment including Substantive Reviews

Ongoing Monitoring

- To **assess** the progress of any changes **over time** of selected sensitive communities and habitats (in nature, intensity and spatial extent) which may be attributable to the effects of aggregate dredging from an agreed monitoring baseline (e.g. via suitable stratified random sampling design) in order to validate predictions made as part of the EIA.
- To determine whether unacceptable impacts are occurring, or if conditions that could lead to unacceptable impacts are developing, within and in the vicinity of new and existing extraction sites.

Substantive Review

- Identify and describe the **actual spatial extent and magnitude of primary and secondary impacts** resulting from **previous dredging activities** and to assess how such impacts may have contributed to the current environmental status.
- To **assess** the progress of any changes **over time** of selected sensitive communities and habitats (in nature, intensity and spatial extent) which may be attributable to the effects of aggregate dredging from an agreed monitoring baseline (e.g. via suitable stratified random sampling design) in order to validate predictions made as part of the EIA.
- To determine if **the licence specific conditions are appropriate and effective** in minimising adverse and unacceptable effects associated with the dredging activity. The substantive review will inform recommendations for any variations to monitoring and/or dredging operations in order to protect the environment and ensure that effective monitoring is maintained.
- To determine if the **licence conditions** have been properly **implemented** and **adhered** to, allowing enforcement if required.
- Where appropriate, establish the **nature and rate of recolonisation** by benthic invertebrates following cessation of dredging.

STEP 3: Post-Extraction evaluation

Objectives: Post-Extraction (normally to coincide with the final Substantive Review)

- Identify and describe the **actual spatial extent and magnitude** of **primary and secondary impacts** resulting from **previous dredging activities** and to assess how such impacts may have contributed to the current environmental status.
- To **assess** the progress of any changes **over time** of selected sensitive communities and habitats (in nature, intensity and spatial extent) which may be attributable to the effects of aggregate dredging from an agreed monitoring baseline (e.g. via suitable stratified random sampling design) in order to validate predictions made as part of the EIA.
- Determine if the **licence** conditions were **appropriate** and **effective** in minimising adverse and unacceptable effects associated with the previous aggregate dredging activity.
- To **establish the nature and rate of recolonisation by benthic invertebrates** following cessation of aggregate dredging (e.g. via reporting on sites within the licence area which have not been dredged for several years).
- To determine whether **mitigation options** (e.g. restoration) should be considered and implemented.

PART 3

Procedural Approaches

Photograph courtesy of Wessex Archaeology & English Heritage

SECTION 6

Benthic Monitoring Survey Design and Planning

The intention of this section is to highlight the 'best practice' survey design and assessment approach which can be consistently followed and is of generic application covering a wide range of cases.

The sequence of steps associated with the regulatory process and the setting of appropriate objectives (outlined in Figure 1 and the previous section) provides a framework for the appropriate design and planning of surveys equally applicable to both infaunal and epifaunal components of the benthos. The successful design, planning and implementation of assessments are conducted as follows:

STEP 1	**6.1 Scoping for Benthic Assessments** 6.1.1 Gathering Information at Scoping Phase 6.1.2 Reviewing Information at Scoping Phase **6.2 Characterisation (Fieldwork Survey Design)** 6.2.1 Characterisation Considersations 6.2.2 Characterisation Survey Design **6.3 Setting the Baseline** 6.3.1 Pre-dredge (Baseline) Considerations 6.3.2 Pre-dredge (Baseline) Survey Design
STEP 2	**6.4 Ongoing Monitoring Surveys** **6.5 Substantive Reviews and Monitoring**
STEP 3	**6.6 Post-Extraction Surveys**

It should be noted that **scoping** forms one of the most critical steps in ensuring the successful completion of the assessment objectives. Time spent undertaking an appropriate, comprehensive and robust scoping 'desk study' will be time well spent and this time **must** be factored into to the planning process, including the necessary iterations often required in liaison with stakeholders to obtain final approval of the scope defining the sampling and assessment needs.

6.1 Scoping for Benthic Assessments

Key points

Scoping should identify:

- existing data and data gaps for benthic characterisation;
- sensitive species and habitats of conservation importance;
- the principal habitat and community types (biotopes);
- the likely zones of impact and changes which will occur;
- assess the cumulative and in-combination effects;
- possible mitigation options.

6.1.1 Gathering Information at Scoping Phase

Scoping is primarily an iterative 'desk-based' exercise with the principal aim of identifying and obtaining existing information that is relevant and useful in supporting the preparation of an EIA for the proposed activity. It includes information on natural processes and environmental resources occurring within the area of interest (e.g. within and around the predicted zones of impact) and to identify any gaps that may prevent the provision of a comprehensive and robust EIA. Clear Terms of Reference and objectives for delivering benthic ecological assessments including an understanding of the criteria used to assess the risks associated with the proposed activity and their significance, should be set out in the scoping study.

Information gathered for scoping should relate to:

- **Hydrography and oceanography** – e.g. sediment transport regime, wave direction and magnitude, tidal/residual currents, horizontal and vertical structure (temperature and salinity) (for technical guidance see Annex A).
- **Seafloor sediments and bathymetry** – e.g. bathymetry, seabed geology, sediment type (for technical guidance see Annex A).
- **Benthic communities and habitats** – Presence and extent of benthic habitats, and their faunal communities, within and around the predicted zones of influence, particularly protected and/or endangered species and commercially important species (for technical guidance see Annex A).

Useful data sources for scoping includes:

- **Marine Aggregate Levy Sustainability Fund (MALSF)** – R&D outputs, reports, information and data collected in support of Regional Environmental Characterisation (REC). All MALSF data is freely available.
- **Aggregate Industry-led initiatives** – Data and outputs produced in support of Regional Environmental Assessment (REA).
- Information gathered in support of applications and monitoring for previous aggregate extraction licences or marine works licences by other sectors (e.g. renewable energy installations and constructions).
- Information gathered by the applicant in support of the current project – e.g. acoustic or sub-bottom data gathered during prospecting or resource mapping.
- **British Geological Survey (BGS)** – Seabed sediment types and underlying geology.
- **HMSO Admiralty** – Detailed bathymetric data.

- **Mapping European Seabed Habitats (MESH)** – Acoustic and benthic data collection protocols, sources/owners of biotope maps produced under the initiative.
- **Scientific literature and other relevant R&D studies** (e.g. Southern North Sea Sediment Mobility Study; MALSF project outputs, Newell *et al.* 2001, 2002, 2004; Boyd and Rees, 2003; Kenny and Rees, 1994, 1996; Desprez *et al.* 2010).

For further information on data sources see Appendix 3.

Regional Environmental Characterisations (RECs) and Regional Environmental Assessment (REAs)

The results of the MALSF funded RECs and industry-led Regional Environmental Assessment (REA) studies are particularly useful in informing environmental characterisation in support of benthic ecological assessments carried out for site specific licence applications. Figure 4 shows the REC boundaries; REAs are being developed within the wider REC boundaries. Although, the RECs and REAs do not cover all marine aggregate producing areas, they do target areas presently subject to most production and prospecting for new marine aggregate resource. Therefore they are most likely to be one of the principal sources of background information on the wider environment and ecological conditions of the seabed required for the site specific pre-application scoping and environmental characterisation.

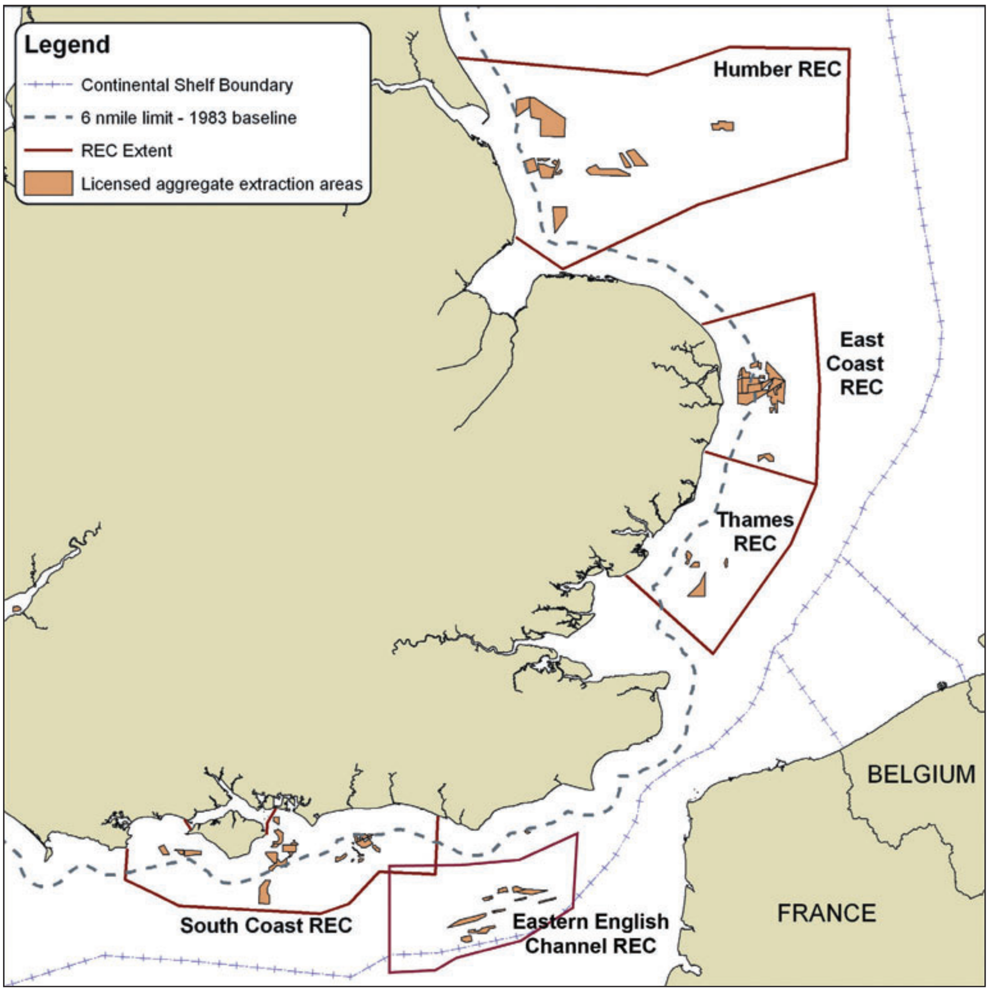


Figure 4. MALSF REC areas (2007-2011); Industry-led REAs are being developed within the wider REC boundaries; (MALSF © Crown Copyright 2011).

It should be noted that whilst the spatial and temporal scales of the REAs and RECs differ slightly, the synergies between the two initiatives allow the data collected under each programme to be integrated, largely because sampling practices and approaches have become standardised in recent years. However, both initiatives are temporally restrained (e.g. they provide an environmental characterisation or assessment for a given time period) and therefore their ability to achieve the objectives of the characterisation assessment will diminish as time elapses between the cessation of the REC & REA surveys and the onset of a new licence application.

Table 1 Main differences between RECs and REAs (information kindly provided by BMAPA).

REC	REA
Government funded programme	Industry funded programme
Broadscale environmental characterisation of wider region	Focussed description of area under the influence of aggregate extraction
Provides general environmental context	Provides impact assessment benchmark
Wider potential end use	Specific impact assessment end use

Where gaps in the existing data do not allow adequate predictions to be made regarding the likely extent and significance of ecological disturbance arising as a result of the proposed activity, further information will need to be gathered by means of additional dedicated surveys. This will require the proposed schedule of work to be defined to address the identified gaps in knowledge and to allow the provision of a comprehensive and robust EIA.

6.1.2 Reviewing Information at Scoping Phase

The review will largely depend on the amount of existing information and data available and hence confidence in identifying and quantifying the benthic habitats and associated benthic communities without undertaking any field work. It should include a comprehensive integrated analysis of existing data using appropriate GIS and statistical software applications to gain as much value from existing data sources as possible. The review should address aspects of the following:

- **Characterisation** – Requires the integration of sufficient macrobenthic community data with information on the physical (habitat) characteristics of the seabed.
- **Identification of the likely Impact Zones (PIZ & SIZ)** – Obtain sufficient information about the proposed development regarding details of the activity (e.g. spatial extent, magnitude, timing, frequency and duration) and the local oceanography (tidal currents and wave action) to establish the potential impact zone. This will include consideration of both primary (or direct) impacts, arising from direct removal of the sediment, along with secondary (or indirect) impacts, arising as result of sediment plumes.
- **Cumulative and in-combination effects** – Identification of all activities occurring within the predicted dredging impact zone which may result in significant cumulative and/or in-combination effects is required. Increasingly, the development of methods that allow more holistic integrated assessments of the effects associated with multiple activities across a number of sectors, will be required for routine EIA purposes. The implementation of an integrated UK maritime policy and unified consenting process under the Marine Management Organisation is expected to increase this focus further with the possible development of integrated (cross-sectoral) assessment guidance in the future.
- **Mitigation options** – In cases where the impact on, or the loss of, sensitive habitats or species is unavoidable, measures should be investigated to reduce this impact where possible.

Expected Outcomes

- Characterisation – The identification of principal habitats and benthic communities within the area of interest including the presence and extent of conservation features.
- Defining the Impact Zones
  - Primary (Direct) Impact Zone (PIZ).
  - Secondary (Indirect) Impact Zone (SIZ)
- Cumulative and in-combination effects
  - Primary (Direct) Effects – Predicting year on year dredging activity (where no previous data exists). Assessing EMS data (where available) using GIS to generate a cumulative footprint of primary impact and therefore defining the actual PIZ.
  - Secondary (Indirect) Effects – The determination of the spatial extent and intensity of indirect impacts during the lifetime of the licence using models. Other more crude estimates using tidal ellipse and grain size data may be used in the absence of a sediment transport model.

  (The same approach can be applied (in an additive way) across a number of licences to generate a map of cumulative effects across a region. This approach, however, may be constrained by the availability and confidentiality of data, since in many instances data from several different aggregate dredging companies will have to be integrated.)
- Mitigation options – Define possible mitigation options, e.g. temporal phasing of active dredge zones and dredging of 'all in' cargos (e.g. no screening).

6.2 Characterisation (Fieldwork Survey Design)

Following scoping if it is decided that not enough is known, then there may be a need to obtain new data. For the purpose of characterisation it is usually sufficient to use single sample stations (e.g. no replication) at a suitable spatial frequency to define the main habitats and their extent, targeting the areas where there is least confidence or where the gaps in spatial coverage are greatest.

Key points

- Characterisation is best achieved through a combination of acoustic mapping of seabed habitat features followed by targeted (stratified) single sample station ground truthing.
- The aim is to determine the status and spatial extent of the benthic habitats and their associated communities.
- Single samples covering a wider area of interest is preferred over replicate sampling from smaller areas.
- The examples presented in the following pages are not definitive and are provided for illustrative purposes only.
- The final number and location of samples should be discussed and agreed in consultation with the appropriate regulatory authorities and their advisors.
- The results of the characterisation survey are used to inform the design of the pre-dredge baseline survey design.

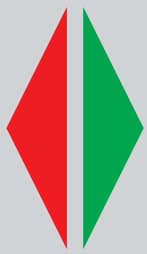
6.2.1 Characterisation Considersations

The amount of additional information which must be gathered to adequately characterise the area and address any gaps in knowledge identified during scoping will largely be site or case specific and therefore, it is not appropriate to define specific total numbers of samples to achieve the objectives of the characterisation survey in these guidelines. However, experience to date suggests that appropriate characterisation can be achieved in data poor areas using approximately 120 individual benthic samples (including grabs and trawls) for a typical licence. In cases where substantial good quality data already exists, new survey effort will be considerably less, and in some cases not required at all. In all cases, the applicant should ensure that the survey plans are undertaken with the approval of the regulatory authorities and their advisors.

High Sampling Scenario

New (previously undredged) site where no previous environmental characterisation surveys have been carried out (in support of any marine works across the various sectors) and no comprehensive biotope map exists.

Or the existing information is very limited in spatial extent or is out of date (i.e. a long time period has elapsed since these data were collected).



Low Sampling Scenario

Comprehensive and recently collected environmental data exists for the area of interest. For example, the application site is situated in an area where an REC or REA has recently been carried out.

The existing environmental data (or biotope map) is of sufficient spatial and temporal resolution to allow confidence in identifying the presence and extent of any habitats or species of conservation importance.

6.2.2 Characterisation Survey Design

Acoustic Surveys

Remote techniques have been employed for many years to both inform and complement the physical sampling methods traditionally employed during benthic surveys. In terms of characterisation surveys, acoustic techniques are useful for delineating the strata present within the area of interest. Such information is extremely important for informing the design of subsequent groundtruthing surveys (to ensure that all strata are adequately sampled) and to identify the presence and extent of any potential features of interest (e.g. geological or sedimentary features, biogenic features of conservation significance and archaeological artefacts).

The value and robustness of a characterisation survey is greatly improved where acoustic data, of sufficient resolution and quality, has been collected to inform and contribute to the ultimate production of a comprehensive biotope map. Therefore, it is recommended that in planning a characterisation survey all existing acoustic data is sourced and obtained and any gaps in information identified and addressed at an early stage. In most instances, it is likely that acoustic data will exist as such information is routinely acquired by the applicant to inform the pre-application prospecting, resource mapping programmes and bathymetric surveys.

Heterogeneous Seabed Surveys

Where there little or no pre-existing biological data and where the acoustic data indicates that the area of interest is *heterogeneous* (e.g. the area of interest contains a number of habitats characterised by different depths or substrate types) a stratified random sampling approach for characterisation is more appropriate (Figure 5). Stratified random sampling should aim to identify and adequately sample all the habitats and associated fauna (biotopes) present within the area of interest, spaced in relation to the predicted zones of impact.

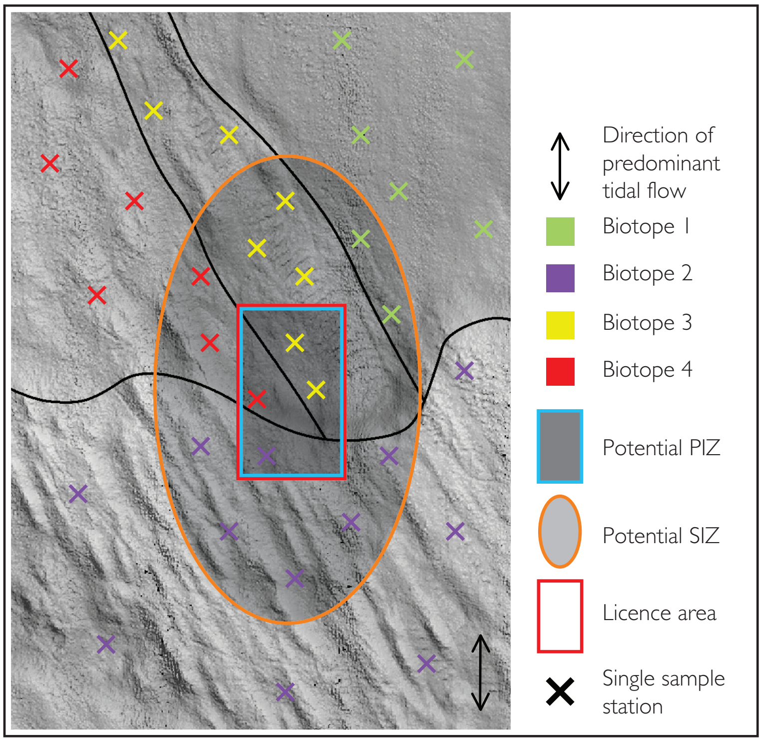


Figure 5. Acoustically defined heterogeneous seabed with random stratified sampling design applied in relation to identified habitat and associated fauna (biotopes) and potential areas of primary and secondary impact. The number and spatial frequency of sampling will depend on how much data and existing knowledge there is about the seabed; and the proposed scale of the dredging operation. Stations located outside the area of impact represent by definition reference conditions. Note this represents a case where there is little or no previous knowledge about the location and extent of biotopes.

Homogenous Seabed Surveys

Where there is little or no pre-existing biological data and where the acoustic data indicates that the area of interest is largely *homogenous* (e.g. no directional gradients in substrate type or depth have been identified) the groundtruthing component of the characterisation survey is likely to adopt a systematic grid approach as shown in Figure 6.

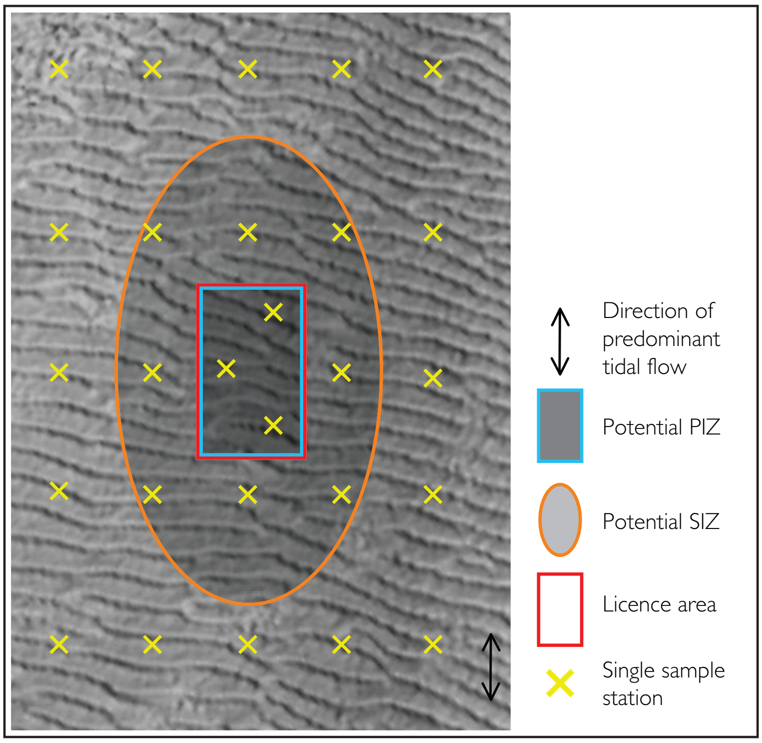


Figure 6. Acoustically defined homogenous seabed with a typical systematic sampling grid applied where stations are spaced in relation to the predicted zones of impact arising from dredging. Note this represents a high sampling case scenario where little or no existing information exists about the biology and habitats of the area. The number and spatial frequency of sampling will depend on how much existing data and knowledge there is about the seabed; and the proposed scale of the dredging operation and its associated footprint of impact.

As the emphasis of a characterisation survey is on the elucidation of spatial pattern and status of biotopes, a strategy involving the collection of single samples from a larger number of stations over a larger spatial area is favoured over repetitive sampling at a smaller number of spatially restricted locations.

Targeted Surveys of Special Interest Features

Where a combination of acoustic and groundtruthing techniques have identified potential habitats or features of conservation or archaeological importance, additional targeted surveys may be required to fully inform the EIA. Additional guidance relating specifically to areas of nature conservation and archaeological interest should be obtained from the relevant statutory nature conservation bodies, English Heritage for England and Cadw for Wales. For example, pre-survey consultation with the relevant nature conservation body will be necessary to identify whether additional survey work is required where particular conservation features are known or suspected. Furthermore, the presence of some species and habitats of nature conservation importance may necessitate a change in sampling method or expansion of the survey to avoid damage and to collect sufficient data to allow a decision to be made concerning the impact of the proposed activity. In the case of temporally defined phenomena (e.g. spawning areas of commercial fish and shellfish species) seasonal considerations may be required when planning associated surveys.

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Further guidance on design considerations and best practice techniques for targeted surveys associated with features of archaeological interest and biogenic reefs is given in the following guidance documents (see also Appendix 3):

BMAPA and English Heritage (2003). Marine aggregate dredging and the historic environment: assessing, evaluating, mitigating and monitoring the archaeological effects of marine aggregate dredging. Guidance Note, British Marine Aggregate Producers Association and English Heritage, London.

JNCC (2001). The Marine Monitoring Handbook. Joint Nature Conservation Committee, Peterborough, 405 pp.

JNCC (2009). The identification of the main characteristics of stony reef habitats under the Habitats Directive. Summary report of an inter-agency workshop 26-27 March 2008. Final Report (v3), 2 March 2009.

Limpenny, D.S., Foster-Smith, R.L., Edwards, T.M., Hendrick, V.J., Diesing, M., Eggleton, J.D., Meadows, W.J., Crutchfield, Z., Pfiefer, S. and Reach, I.S. (2010). Best methods for identifying and evaluating *Sabellaria spinulosa* and cobble reef. Aggregate Levy Sustainability Fund Project MAL0008. Joint Nature Conservation Committee, Peterborough, 134 pp.

6.3 Setting the Baseline

Key points

- The examples of survey design presented in this section are not definitive.
- They do, however, highlight the importance of stratified random sampling in the design which is determined by a combination of the seabed biotopes and the impact zones associated with dredging.
- In order to standardise the sampling effort, we recommend taking a fixed number of samples from a given area (termed the *location*) within each strata.
- The precise number of locations (boxes) for any given strata will vary depending on the extent of the strata to be sampled.
- The final number and position of locations (boxes) should be discussed and agreed in consultation with the appropriate regulatory authorities and their advisors.
- The examples provided (Figures 7, 8 and 9) use one location (or sample box) per strata for illustrative purposes only. They are not intended to represent definitive survey designs for all cases.

6.3.1 Pre-dredge (Baseline) Considerations

It is important to ensure that the survey design adopted is able to detect possible adverse changes caused by dredging that allow a sensible interpretation of compliance with the licence conditions and can validate predictions made as part of the EIA. There are many ways in which this can be achieved. However, it is beyond the scope of the present guidance to provide a critique of the different survey designs available to assess temporal and spatial impacts on benthic marine ecosystems. Rather, this guidance aims to set out the basic principles associated with the assessment and monitoring of marine aggregate extraction sites, emphasising the most commonly adopted and agreed approaches applied in practice. It should be noted that there is not a 'one size fits all' approach, but survey designs will utilise well known techniques to detect effects at different spatial scales and gradients of impact, further details of which can be obtained from a number of sources (e.g. Underwood, 1991, 1992, 1993, 1994, 1996, 1997, Kelaher *et al.* 1998, Benedetti, 2001, Skilleter *et al.* 2006). **However, in all cases it is important to ensure that the final baseline survey design and monitoring plan is approved by the regulatory authorities and their advisors prior to fieldwork commencing.**

Baseline sampling stations should be positioned at pre-determined (**and agreed**) locations within the main characterisation survey area. The survey locations should be sampled according to a stratified random sampling design. Data acquired for these locations will form the baseline for subsequent 'ongoing monitoring' studies. The survey design (Figures 7, 8 and 9) utilise six single grab samples positioned randomly within an area measuring 250,000 m^2 (or a 500 m by 500 m location sampling box). Under this survey design each 'sampling box' would represent a single location from within a given pre-determined strata. The number and size of sample locations will ultimately depend on a number of factors, not least the type, extent and dynamics of the identified biotopes and special interest features and the scale of the dredging operation. However, the survey design employed should allow the detection of impacts arising as a result of the dredging activity in order that the regulator can verify predications made as part of the EIA (regarding spatial extent and magnitude of impacts) and assess compliance with the associated licence conditions.

Survey Timing

Whilst the primary purpose of the characterisation survey is to identify the extent and type of principal habitats and their associated benthic communities within and around the area of dredging, it also informs the baseline survey design and the location of ongoing monitoring stations. In some instances the amount of existing data and knowledge of an area (as in the case of licence renewals) will be sufficient to largely confine the characterisation step to a desk-based study or review. In this case, any additional characterisation sampling required (to improve confidence or to confirm the status of known benthic communities and habitats) could be undertaken at the same time as the baseline (pre-dredge) survey. However, it should be noted that it is more common to conduct the baseline survey as a pre-dredge survey following the granting of a dredging licence as this ensures the minimum amount of elapsed time between the baseline and the onset of active dredging (see below). It should be noted that with increased elapsed time between baseline sampling and the onset of dredging, the baseline data are likely to become less reliable for the purpose of subsequent monitoring and assessment. Moreover, the risk of falsely attributing any natural changes in the benthos to the impacts of dredging increase with increasing time between the baseline survey and the onset of dredging. Therefore under the circumstances, where more than one year has elapsed between baseline sampling and the onset of dredging, additional more up-to-date baseline data may be obtained by means of an additional 'pre-dredge' survey.

If the spatial extent and status of the significant habitats and communities are not well known prior to the characterisation survey being undertaken then it is also advisable to plan a separate (pre-dredge) baseline survey which can be appropriately designed utilising the new characterisation survey data. It is therefore advisable that the characterisation and baseline (pre-dredge) surveys are undertaken separately. A typical case would therefore require a characterisation survey informed by the scoping exercise, to be followed by a pre-dredge (baseline) survey which would satisfy the monitoring and substantive review objectives along with any licence specific permit conditions.

Setting the Baseline for a Renewal Application

An additional consideration when setting the baseline is the status of the proposed aggregate extraction area for which a licence is being sought (e.g. is it a new application or a renewal).

Where a licence renewal is being sought, the pre-dredge data acquired is not strictly a baseline (as the site has already been subject to previous dredging activity). Therefore, under these circumstances the EIA process places a requirement on assessing how previous dredging activities and associated impacts have contributed to the current environmental status of the site. Indeed an opportunity exists to combine the final assessment of the previous licensed site with the objectives for baseline assessment for the new licence. Additionally, the footprint of previous dredging impacts needs to be considered in order to effectively locate stations that are representative of reference and secondary impact conditions.

In these circumstances, there remains a requirement for data to be collected (prior to any further dredging) to evaluate the current status of the renewal area and to subsequently allow predictions to be made (and ultimately validated) regarding the extent and significance of additional impacts likely to arise as a result of the proposed additional dredging activity.

6.3.2 Pre-dredge (Baseline) Survey Design

Heterogeneous Seabed Surveys

A robust stratified survey design, for the purpose of baseline sampling should aim to achieve an adequate and balanced density of sampling within the predicted impact zones (e.g. the PIZ and SIZ determined during scoping) along with an adequate density of sampling within comparable strata from adjacent reference (un-impacted) locations (Figure 7). For all baseline surveys, a dataset that incorporates station locations from within the predicted zones of impact (PIZ and SIZ) and in comparable reference areas (which are representative of the un-impacted environment) should ultimately allow any subsequent changes that are attributable to dredging to be delineated from the effects arising as a result of natural processes operating across the survey area.

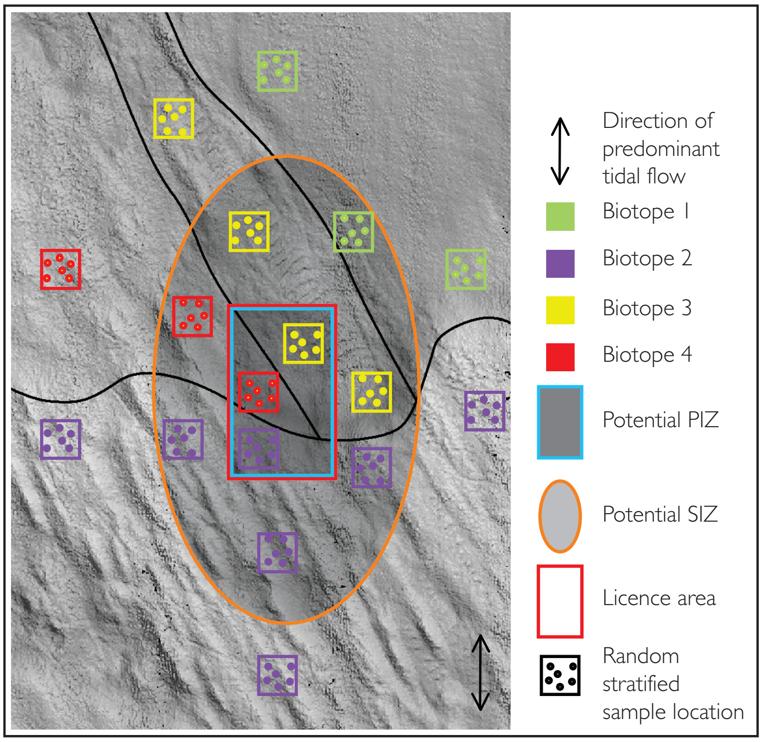

Figure 7. Stratified random sampling locations in defined strata (as determined from scoping and characterisation surveys) and positioned to include predicted primary and secondary impact zones along the major impact pathways. Note the actual number and position of sample locations should be agreed in consultation with the Regulator.

Homogenous Seabed Surveys

Where the seabed is largely homogenous, within and adjacent to the predicted zone of impact (such as some areas of the Bristol Channel and off the east coast of England), a transect (Figure 8) or grid based (Figure 9) design may be adopted for the positioning of baseline stations. In most cases, where the effects can be predicted to occur along well-defined gradients associated with such factors as tidal currents, then weighted transects whose orientation follows the major axis of the tidal ellipse are most suitable. This results in forming an asymmetrical pair of transects (Figure 8).

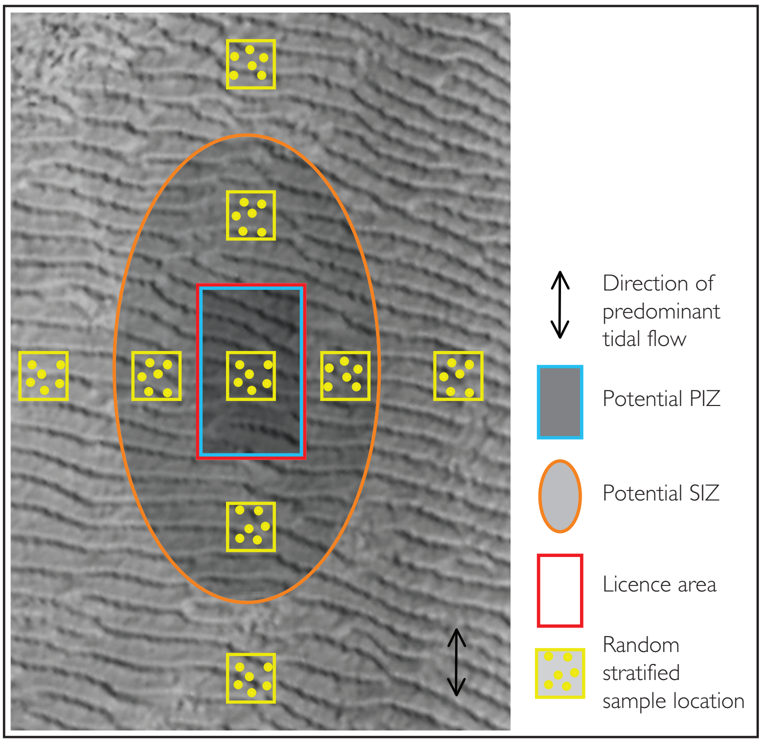

Figure 8. Impacts predicted to occur along clearly defined gradients where the seabed is of uniform habitat type (e.g. mobile sand waves), then two transects of stratified random sample locations (boxes) orientated along the major impact pathways at a spatial frequency of sampling dependent on the proposed scale of the dredging operation is appropriate.

In instances (albeit rare) where the effects are not predicted to occur along clearly defined gradients away from the dredging activity, sample locations should be symmetrically positioned according to a 'radiating' grid design (Figure 9). Such a design allows for uncertainties in the likely spatial extent and pathways of impacts to be accommodated.

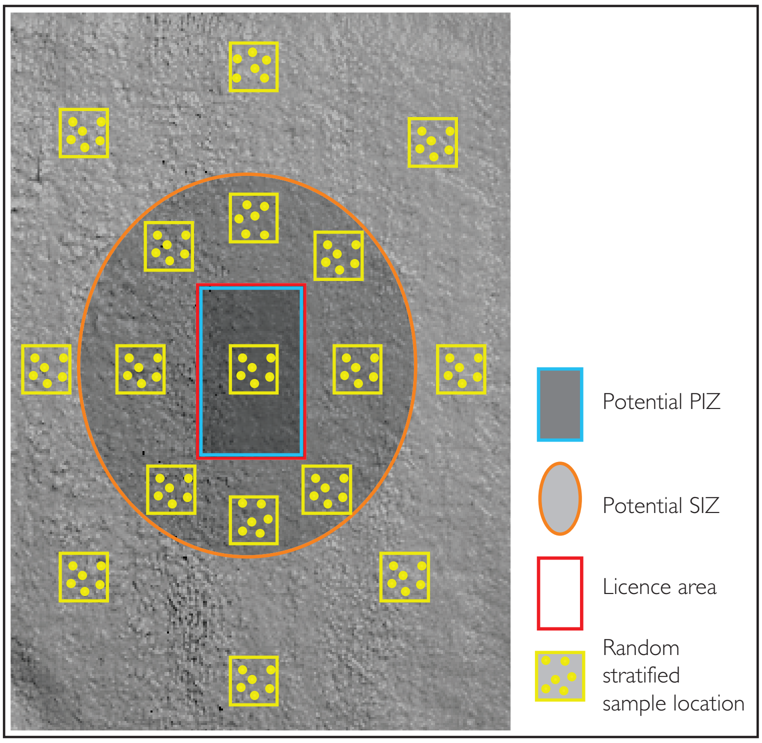

Figure 9. Systematic (radiating) grid of stratified random sample locations where there is no known predominant directional gradient of effect. The spatial frequency of sampling will be dependent on the proposed scale of the dredging operation.

In order to arrive at a robust stratified random sampling survey design, which will be effective in distinguishing natural variability from impacts arising as a result of dredging, a number of considerations should be taken into account. Most importantly, the survey should incorporate replication within each of the strata identified (in Figure 7, eleven strata have been identified based on a combination of seabed biotopes and dredging impact zones). The pattern of replication, within each strata, is based upon six sample stations positioned randomly within a location (box) measuring 500 m by 500 m along a line perpendicular to the predicted impact pathways. This approach also has the added advantage of having boxes replicated within some of the strata.

Sample Replication and the Power to Detect Change

The number of replicate samples and sample locations (boxes) required to detect a certain level of change in a given parameter (e.g. number of species, density of individuals) is very much site and time specific and is highly dependent on the inherent variability exhibited by that parameter in a given area and time. Similarly, the level of replication required to detect, a 10% change in a parameter in a given area and time will not be the same for all parameters. Although, statistical power analyses can be applied to determine what level of replication is required to detect a certain level of change in a given parameter, it is often the case that in areas where the substrate exhibits a high level of natural spatial or temporal variability (typical of marine aggregates), the level of replication or density of sampling, required is prohibitively high. Therefore, the level of replication employed must reflect a balance between the statistical requirements for assessing certainty (at a given level), the magnitude of change required to be detected, the additive adverse effects of sampling on the environment (e.g. it would be undesirable to subject a sensitive, but variable habitat to high levels of destructive sampling) and resource constraints.

A comprehensive account of power and precaution in the assessment of environmental impacts is given by Underwood and Chapman (2003).

Given the above considerations, sample replication may take the form of repeated sampling within a pre-determined location defined by either: a range ring, sampling within a pre-defined 'treatment or reference box' or sampling along a line perpendicular to the predicted major impact pathway. **In each case such judgements will inevitably be site specific and should be finalised in consultation with the regulator and their advisors, but for the purpose of resource planning and to develop an initial survey design the practitioner should follow the illustrative designs presented in this guidance.**

Placement of Sample Locations within the Primary and Secondary Impact Zones

The rationale for positioning sample locations (boxes) peripheral to the centre of dredging activity but within the licensed area is that (by analogy with the 'mixing zone' concept applied to waste discharges: Water Authorities Association, 1988) any standards governing permissible biological changes in the surrounding environment would not be expected to be met at the point of immediate impact. This is equivalent to the concept of a SIZ.

Sampling at one or more of these locations is often necessary due to:

- Dredging activity proceeding in sequence across zones within a licensed area. Therefore, informed placement (with consideration of the proposed dredging programme) of a number of sample locations (boxes) within the dredging area (Figure 7) increases the likelihood that one or more locations will actually fall in the area subsequently dredged.
- An interest in the recovery process following cessation of dredging within parts of the licence area should also be addressed by the placement of sample locations (boxes).
- A management interest in the responses of animal populations to ongoing disturbance, especially if there are sensitive features within the licence area that are being protected by spatial or temporal dredging exclusions (e.g. fish nursery areas

and *Sabellaria spinulosa* reef). To achieve this it is important to ensure that some sample locations are positioned in areas where dredging will occur (or has occurred) corresponding to each survey period.

Placement of Reference Stations

It is recognised that identifying suitable reference locations for placement of reference stations (e.g. stations that are representative of the un-impacted environment) is often problematic for a number of reasons namely:

- Proximity to other marine aggregate extraction areas (e.g. is the licence area an isolated site or is it located within a 'block' of licence).
- Proximity to areas affected (and potentially impacted) by other sector activities (i.e. dredging disposal sites, renewable energy installations etc.).
- Areas where physical sampling of the seabed is not possible due to obstruction by cables, pipelines, wrecks or exclusion zones etc.

Whilst it is unlikely to identify sufficient reference sample locations (boxes) to cover all eventualities, it is recommended that every effort is made to identify and incorporate an adequate number of reference locations into the survey design. There should be approximately equal numbers of reference and impact locations.

Time-Series Data and Environmental Assessment Reference Stations (EARS)

There may be uncertainty in assessing the significance of dredging induced changes to benthic habitats and their faunal communities where the temporal context of such changes is not fully understood. In order to put dredging induced changes into a temporal context there is a need to understand the patterns and processes underlying natural variability in habitat status and associated benthic populations over time. This is reflected in the principles of Before-After-Control-Impact (BACI) and 'beyond BACI' experimental designs for detecting anthropogenic impacts which require an appropriate temporal baseline for both treatment and control (or reference) sites (Underwood, 1991, Underwood *et al.* 2000).

In an attempt to provide some consistency and continuity in assessing temporal variability, Cefas has initiated a set of Environmental Assessment Reference Stations (EARS) which are strategically placed in the vicinity of ongoing and likely future aggregate extraction activities (Figure 10 and Appendix 4). At each station, four replicate mini-Hamon grab samples are taken from within a 200 m diameter range-ring. Although, the present set of stations does not provide comprehensive regional coverage, it is hoped that it can be extended to cover other regions of interest and be incorporated where appropriate into the industry-led REA process. The existing EARS data (macrofaunal abundance and biomass data and sediment particle size data) are accessible to both regulators and industry and are intended to help assess the effects of local and wider scale impacts and to provide an important temporal component to the evaluation of environmental change.

A commitment to sample relevant EARS as part of an EIA could provide valuable evidence of temporal trends and reduce the risk of falsely attributing changes in benthic communities to dredging when natural events are the main cause[3]. It is therefore advisable, and for the benefit of all, if sampling of these stations be undertaken at the same time as the baseline survey.

3 However, at present there is no agreed or funded monitoring programme to sustain sampling at these locations.

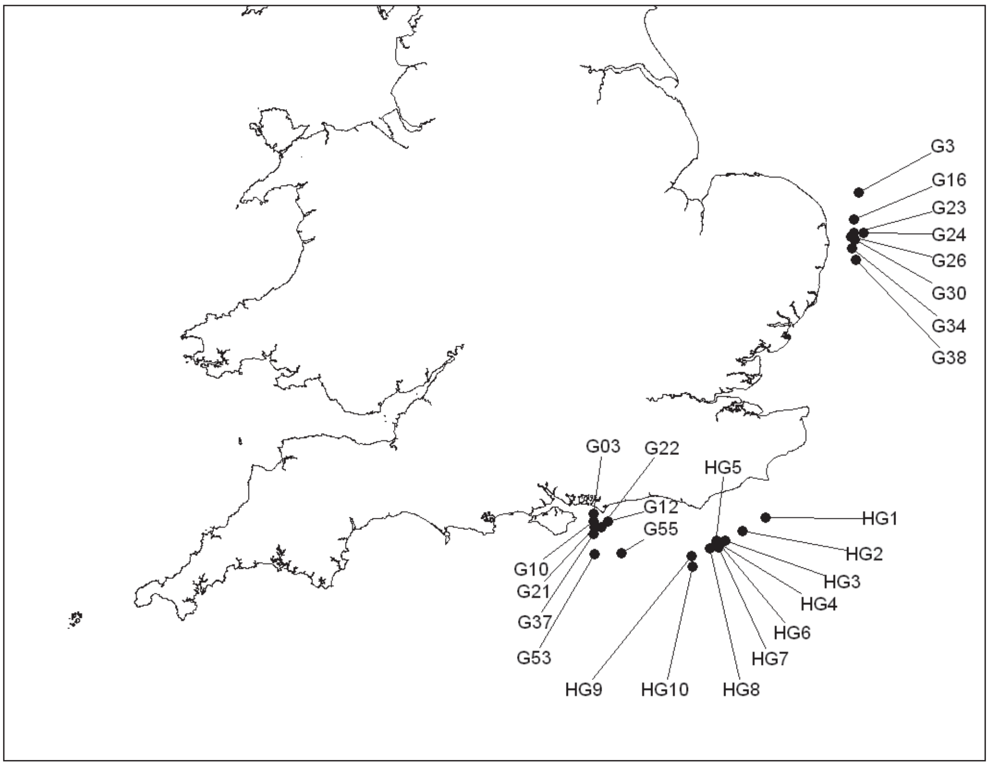

Figure 10. The location of Cefas Environmental Assessment Reference Stations (EARS) (Crown Copyright Cefas).

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6.4 Ongoing Monitoring Surveys

Frequency of Ongoing Monitoring Surveys

The frequency of ongoing monitoring surveys required is largely site and licence (permit condition) specific and will depend on a number of considerations including:

- The sensitivity of the environment within which the dredging is taking place.
- Amounts of material to be removed over a given area and time.

In general, the frequency of monitoring is likely to be higher in the period immediately after the onset of dredging and then lower following assurance that the environmental consequences are in agreement with predictions made in the EIA, and are acceptable and stable between surveys.

Timing of Ongoing Monitoring Surveys

Ongoing monitoring surveys should be carried out at the same time of year as the baseline survey. If the same month cannot be accommodated then sampling in the same season should at least be ensured. This allows temporal compatibility between the data sets and reduces the effects of inter-seasonal variation in any comparisons made (particularly important in relation to the timing of epibenthic surveys where results are likely to be variable on a generally predictable seasonal basis but also inter-annually).

In ideal circumstances, baseline and subsequent monitoring surveys should be carried out in the period between February – April (i.e. before the main recruitment period of pelagic larvae which generally occurs from early summer onwards).

Ongoing Monitoring Survey Design

The survey design for ongoing monitoring will be decided on a case specific basis in consultation with the Regulator, but as a minimum it would likely target the most **sensitive habitats** and **species** as a sub-set of the pre-dredge (baseline) survey locations. Indeed sampling to generate the baseline (or pre-dredge data points in the case of a licence renewal) should form the basis for the selection of 'ongoing' monitoring stations. It is important that the design and selection of monitoring locations be undertaken in consultation with the Regulator and that this should form part of an agreed monitoring plan included in the EIA during Step 1 of the Regulatory Process (see Figure 1). This will ensure that sufficient and appropriate sample data is available at the time of substantive review.

As part of an overall quality assurance strategy, it is important to check on the continued validity of stations selected as representative of impacted and reference conditions. Therefore, some allowance must be made for the possible modification in locations in response to unanticipated anthropogenic or natural influences.

The validity of stations selected as representative of the PIZ (dredged areas) can be easily confirmed through the interrogation of EMS data and sidescan sonar records (see Figure 3). EMS data is produced by all vessels dredging on a Crown Estate licence in UK waters and consists of the date, time and position of all dredging activity at 30 second intervals. However, due to the nature of the time step involved in recording positions the actual location of the draghead and the recorded EMS data may be significantly different (up to ± 150 m).

6.5 Substantive Reviews and Monitoring

Frequency of Substantive Reviews

Substantive reviews normally occur every five years and typically require a comprehensive assessment of monitoring data to be carried out in order to assess whether the licence specific permit conditions are appropriate and effective in minimising any adverse and unacceptable effects associated with dredging. If, as a result of this assessment, changes are identified to be greater in extent or magnitude than those anticipated then the extent of such changes would need to be further explored by means of additional survey work and sampling, usually involving a repeat of the full pre-dredge (baseline) survey. Where unacceptable impacts are further identified and verified this may lead to the permission being suspended or revoked.

Timing of Substantive Reviews

Monitoring surveys to inform the substantive review should be carried out wherever possible at the same time of year as the baseline survey. This ensures temporal compatibility between all relevant data sets and allows a robust evaluation of the progress of any changes over time (in nature, intensity and spatial extent) which may be attributable to the effects of dredging. In addition it allows an assessment of whether licence specific conditions are appropriate and effective in minimising adverse and unacceptable effects associated with the dredging activity and to determine if the licence conditions have been properly implemented and adhered to.

Substantive Review Survey Design

A substantive review of licence permit conditions is best informed initially by comprehensively assessing the existing pre-dredge and ongoing monitoring survey data to demonstrate that changes are in agreement with expectations. Where changes are observed to be beyond those expected then further sampling to assess the full spatial extent of such changes may be required, normally a repeat of the full baseline sample locations. This should allow a full assessment of possible changes in the boundaries and extent of the principal habitats and special features of interest.

Compatibility and Integration of Historic Monitoring Data

For a substantive review all previous data generated during characterisation baseline surveys and ongoing monitoring, should be integrated to allow a comprehensive assessment of the nature and progress of any changes over time that may have occurred due to dredging activity.

In many cases data may not be directly compatible due to changes in survey methods or sampling protocols in response to the development of new techniques and changing standards over time. This is most likely in the case of dredging renewals. However, this should not preclude utilisation of all available and relevant data. Rather, all previous monitoring data should be considered and utilised during the substantive review process and where inconsistencies in data or techniques are identified, they should be stated. This allows any conclusions drawn from analyses of the integrated data sets to be interpreted in the correct context. If any changes to survey methodologies are proposed, careful consideration must be given to ensure comparability with previous surveys (through consultation with the Regulator and their advisors).

6.6 Post-Extraction Surveys

Frequency and Timing of Post-Extraction Surveys

Post-extraction monitoring surveys are typically timed to correspond with monitoring surveys. They are carried out to inform the final substantive review in order to best utilise resources employed to fulfil the dual (and often overlapping) objectives.

MMG 1 states 'Where monitoring indicates that the marine environment outside the dredged area is affected as a direct result of the dredging activity, the Secretary of State will consider carefully what action is needed to minimise further damage or, if considered necessary, to restore the area'. Furthermore, in MMG 2 it states 'the monitoring results shall be used to produce a report describing the condition of the seabed following the cessation of dredging within the permitted area. In the event that the state of the seabed, as described in that report, gives cause for concern, the Secretary of State will consider what actions, if any should be taken, including remediation at the cost of the Operators'.

It should, however, be noted that this situation should not arise where monitoring undertaken during the lifetime of the licence is effective in providing an early warning of any adverse changes arising due to dredging which may require further assessment (such assessments would be considered in relation to the specific licence conditions).

Post-Extraction Survey Design

Post-extraction monitoring is best informed by carrying out a repeat of the full original (pre-dredge) baseline survey (including both acoustic and ground-truthing components). It is for this reason that best use of resources can be achieved by combining post-dredge monitoring surveys with those conducted to inform the final substantive review.

SECTION 7

Checklist of Survey Objectives at Each Step of the Assessment Process

Table 2. Checklist of survey objectives at each step of the assessment process. Coloured text corresponds to principal regulatory assessment steps as depicted in Figure 1.

	Pre-application: New Licence (Characterisation and Pre-Dredge Baseline)	*Pre-application: Licence Renewal (Characterisation and Pre-Dredge Baseline)*	*Ongoing Monitoring*	*Substantive review*	*Post-Extraction*
To provide a **spatially extensive description** of the seabed environment within and around the expected impact zones (PIZ and SIZ) including the identification of **important/ sensitive habitats and species**	✓	✓	–	–	–
Identify and describe the **predicted spatial extent and magnitude** of the possible **primary and secondary impacts** from the proposed activity	✓	✓	–	–	–
To identify and describe the **actual spatial extent and magnitude of primary and secondary impacts** resulting from **previous aggregate dredging activities** and to assess how such impacts may have contributed to the current environmental status	–	✓	–	✓	✓
To assess the **progress of any changes over time** (in nature, intensity and spatial extent) which may be attributable to the effects of aggregate extraction	–	–	✓	✓	✓
To determine whether **unacceptable impacts are occurring**, or if conditions that could lead to unacceptable impacts are developing, within and in the vicinity of new and existing extraction sites	–	–	✓	✓	–
To determine whether the **licence conditions are appropriate** and that they are having their desired affect of minimising the effects of aggregate extraction	–	–	–	✓	–
To determine whether **historic licence conditions were appropriate** and that they had the desired affect of minimising the effects of aggregate extraction	–	–	–	–	✓
To determine whether **licence conditions** have been properly **implemented and adhered to**	–	–	–	✓	✓
Where appropriate, establish the **nature and rate of recolonisation** by benthic invertebrates following cessation of dredging	–	✓	✓	✓	✓
To determine whether mitigation options (e.g. restoration) should be considered and implemented	–	–	–	–	✓

PART 4

Annexes
Operational Guidance

Courtesy of MES Ltd

ANNEX A
Field Sampling Methods and Conduct

The following sections provide details of best practice field survey techniques and implementation of standard operating procedures at sea for the purpose of marine aggregate benthic assessments.

A1 Oceanography

The following sections provide details of best practice field survey techniques and implementation of standard operating procedures at sea for the purpose of marine aggregate benthic assessments.

Introduction

It is generally understood that the hydrodynamic regime (tidal currents and waves), in combination with sediment source, largely determines the characteristics of seabed sediments and it is this which ultimately determines a significant part of the broad scale community patterns we observe off our coasts. It is therefore apparent that any changes in the status of benthic assemblages in areas which have been subjected to commercial aggregate extraction will need to be referenced against variations in the natural sediment particle size distributions and the hydrodynamic regime. The local hydrodynamics will also affect the dispersal of sediment plumes arising from marine aggregate extraction. It is essential that such information is accounted for in the design of the baseline benthic surveys in order to address any secondary consequences of dredging, especially the release and then re-deposition of fines beyond the boundaries of the extraction permit.

Useful sources of hydrodygraphic data include:

- The United Kingdom Hydrographic Office (UKHO)
- The British Oceanographic Data Centre (BODC)
- Cefas WaveNet
- Proudman Oceanographic Laboratory (POL)

It is likely that for areas with a history of aggregate extraction the hydrodynamic regime may already be well known and therefore new surveys to characterise it may not be required. For areas where this is not the case, a range of oceanographic techniques can be employed to help ascertain the hydrodynamic regime and, in particular, to determine the wave climate regime and the strength and direction of tidal currents for a given locality.

For a comprehensive review of oceanographic techniques which may be employed during surveys of marine aggregate extraction sites, reference should be made to general texts such as UNESCO (1988, 1993), Emery and Thompson (1997), ICES (2000) and DTLR, 2002).

A2 Acoustic Techniques

Remote acoustic methods have been used for many years now to complement the direct sampling employed for benthic surveys. Acoustic techniques can be used to inform survey design by providing a base map which allows efficient and thorough sampling strategies to be designed with reference to underlying spatial patterns and distributions. Data from remote acoustic survey can be analysed and interpreted, using expert knowledge or data from direct samples to produce maps of physical and biological features of the seabed. In practise, sidescan sonar systems are routinely employed, in conjunction with a number of ground-truthing techniques, for the purposes of characterising seabed habitats. However, a number of more recent developments in high resolution side scan sonar and Acoustic Ground Discrimination Systems (AGDS) have proved effective in identifying the presence and extent of certain habitats and features of conservation importance. Additionally, a number of acoustic techniques are routinely employed for the purpose of bathymetric surveys and these include single beam and multibeam (or swath) systems.

Each of the different methodologies has its own advantages and disadvantages (see Table 3, Kenny *et al.*, 2003 and Bale and Kenny, 2005) and the most suitable technique or combination of techniques depends upon the requirements and constraints of each specific application. Increasingly the 'collect-once use-many times' approach is adopted and this enables multiple systems to be deployed in combination with each other. Further guidance on the risk of injury and disturbance to marine fauna arising as a result of the utilisation of acoustic techniques routinely employed for seabed mapping is given in JNCC 'Guidelines for minimising the risk of disturbance and injury to marine mammals from seismic surveys' (Appendix 3). It should be noted that it is the responsibility of the survey contractors to ensure that their operations are not in breach of national regulations (Appendix 3).

Table 3. Summary of remote acoustic systems (for more detailed review of acoustic methods refer to Eleftheriou and McIntyre; 2005)

System	*Use*	*Resolution*	*Relative Cost*	*Environmental Applications*
Sidescan Sonar	Sediment texture and features	Very High (100% coverage possible)	Low to High (depending on system)	Identification and monitoring of specific habitats, sediment transport pathways etc. Broadscale base map to inform direct sampling survey design
Acoustic Ground Definition System (AGDS)	Line bathymetry and sediment discrimination	Low spatial resolution (>10 m), full coverage requires interpolation	Low	Habitat mapping Can help inform direct sampling survey design
Echo-Sounder (single line bathymetry)	Line bathymetry	<100% – poor spatial coverage	Low	Detection of broadscale features Broadscale base map to inform direct sampling survey design
Swath Bathymetry	Bathymetry and sediment discrimination (from backscatter)	Very High (100% coverage possible)	Moderate to High (entry level system). High performance systems very expensive	100% bathymetric coverage and detection of topographical features
Sub-Bottom Profiling	Sediment layers and shallow geology	Vertical resolution varies with frequency	High	Can help to infer habitat distribution through identification of geological features

A3 Seabed Sampling

A3.1 Optical Methods

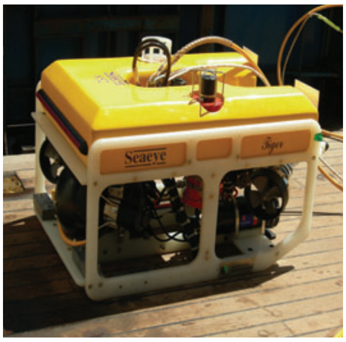
Introduction

Underwater video and stills photography are valuable, non-destructive methods for the assessment of all types of seabed habitat. They can be particularly useful over hard and consolidated ground where the sampling efficiency of other physical sampling methods is low. Remotely controlled underwater photography has been in use for a number of years to obtain static images of the seabed, and high quality images can be obtained which enable the identification of much of the macro-epifauna present. These images cover a small area of seabed and while useful in pilot surveys, do not readily provide information on the wider spatial distribution of faunal communities.

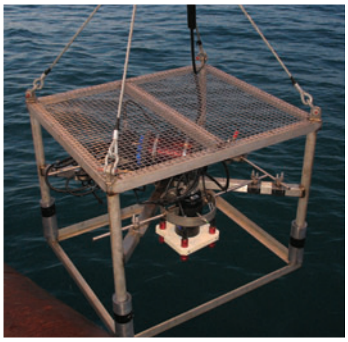
Equipment

To allow wider spatial coverage of the seabed, photographic and video cameras have been mounted on a variety of platforms. Cameras have also been attached to a variety of grabs to provide real time images of the nature of the substratum being sampled. However, in most instances platforms will fall into one of the following categories:

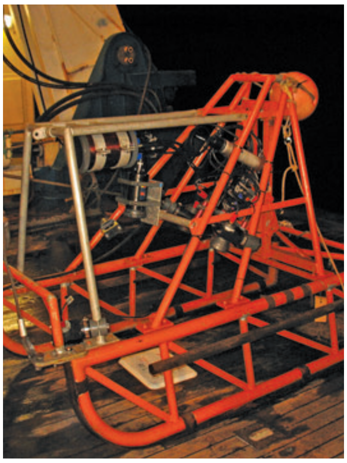
Devices which are capable of moving or being directed under their own power such as Remotely Operated Vehicles (ROVs).



Samplers which are lowered to a point above the seabed (e.g. drop cameras).



Devices which are towed along the seabed (e.g. camera sledges).



Samplers which are lowered onto the seabed and penetrate the sediment to acquire a vertical profile image of the sediment (e.g. Sediment Profile Imaging (SPI) camera).

Application of Optical Methods

In the last ten years the adoption of video techniques has become more widespread with many systems now commercially available and included as a matter of routine in marine ecological impact studies. The integration of video techniques is now common place in virtually all sea bed habitat mapping programmes. For an up-to-date and comprehensive review of underwater video techniques the outputs from the Mapping European Sea Bed Habitats project (MESH) should be consulted (Coggan *et al.*, 2007) in identifying:

The presence and extent of features of conservation interest or of commercial value (e.g. Maerl beds or fish spawning/breeding areas);

- the spatial extent of dominant habitats and benthic communities (assemblages); and
- the assessment of the condition of features.

It is likely that a towed or drop down video will be the preferred option. However, in the latter case, the enhanced manoeuvrability of a Remotely Operated Vehicle (ROV) may prove to be the better option. Although the ability of the ROV to work and hold station can vary hugely depending on water depth (length of cable), vessel, current speed and class of ROV.

A key aspect of video interpretation, in addition to the identification and enumeration of benthic species, is the classification of sediment and habitat types using a standardised approach. A degree of experience is required for an analyst to become proficient and consistent in classifying sediments seen on video footage. Of considerable aid are photographic atlases with standard sedimentological descriptions, such as the ISSIA (Irish Sea Seabed Image Atlas – Allen and Rees, 1999), and the recently developed MESH Habitats Signatures database (MESH, 2006). In addition the biota may indicate the type of substrate; for instance burrows are generally found in fine sand to muddy sediments, whereas attached epifauna, such as dead man's fingers (*Alcyonium digitatum*), require a hard substrate for attachment, which could indicate shell debris or stones (possibly slightly covered by finer sediment).

Video and photographic data can be subjected to a number of levels of analysis depending on the initial survey design and the level of information required from the analysis. Any type of data analysis will probably require at least two viewings of the video footage, one to assess the quality and determine crude habitat boundaries where applicable and a second, more formal viewing, to apply the decided processing methodology (objective enumeration, quantification or qualification of fauna).

Photographic stills or video freeze-frames may be treated as quadrat samples and therefore species counts or percentage cover estimates can be undertaken, providing fully quantitative, semi-quantitative, or SACFOR information (Superabundant, Abundant, Common, Frequent, Occasional and Rare) a scale of relative abundance developed by Hiscock (1996). Each image is often analysed using a physical or digitally generated grid to facilitate counting or estimating cover (Service and Golding, 2001; Rees, 2009). Where the area of field of view can be calculated, absolute species density values can be derived.

Semi-quantitative Underwater Video Assessments

Semi-quantitative data extraction requires the length of video transect to be known. Where the field of view remains constant (from a towed video sledge over fairly level ground) and visibility is good, direct counts may be made of all the organisms encountered over a fixed distance to derive measures of absolute density. Where visibility is poor, a line-transect method may be used (Bergstedt and Anderson, 1990), dividing the image into a number of corridors and making species counts for each corridor. Where the field of view is constantly changing (through changes in topography, altitude of the camera or visibility) and abundance values cannot be easily determined, species-time methods may be used to quantify the visual data, counting the number of each species encountered in a fixed time to derive estimates of relative abundance. Published, peer-reviewed literature provides further details regarding these techniques and, importantly, describes which technique is appropriate given different survey methods and conditions (Michalopoulos *et al.,* 1992; Bergstedt and Anderson, 1990; Kimmel, 1985; Malatesta *et al.,* 1992).

A relatively rapid method of semi-quantitative analysis is scoring the relative abundance of species on a categorical scale. The SACFOR scale is often used, usually in combination with substratum descriptions. Such analysis is appropriate for the application of local and national habitat classification schemes (e.g. JNCC's biotope classification developed by Connor *et al.* (2004)).

Qualitative Underwater Video Assessments

Qualitative analysis usually involves a visual interpretation of the material accompanied by some degree of faunal identification. Photographs can be used to help identify species that commonly occur on video footage. However, still images taken as freeze-frames from video footage are often of lower resolution than photographs, due to poor lighting or image smearing from movement in the video footage. A high degree of certainty that the same species are being observed in both video and still images can only be guaranteed by freeze-framing the video footage at the exact time/location that the still image was taken and showing the same section of seabed. Still images often enable the identification of taxa such as sponges, bryozoans and hydroids that are hard to identify even to family level from video footage. Finally, in some situations the more powerful lighting of a stills camera strobe may reveal colours that are difficult to discern on video footage. This may prove particularly important when looking for calcareous and/or red algae such as Maerl, or particular sponges.

Underwater Images in Low Visibility

In low visibility conditions (caused by high levels of turbidity in the water column) the acquisition of good quality images may not be possible using the conventional systems described above. Under such circumstances, quality images of the seabed may still be acquired using a camera system that incorporates a freshwater lens (Figure 11). However, such systems may still fail to obtain useable images in areas where high levels of turbidity are encountered.

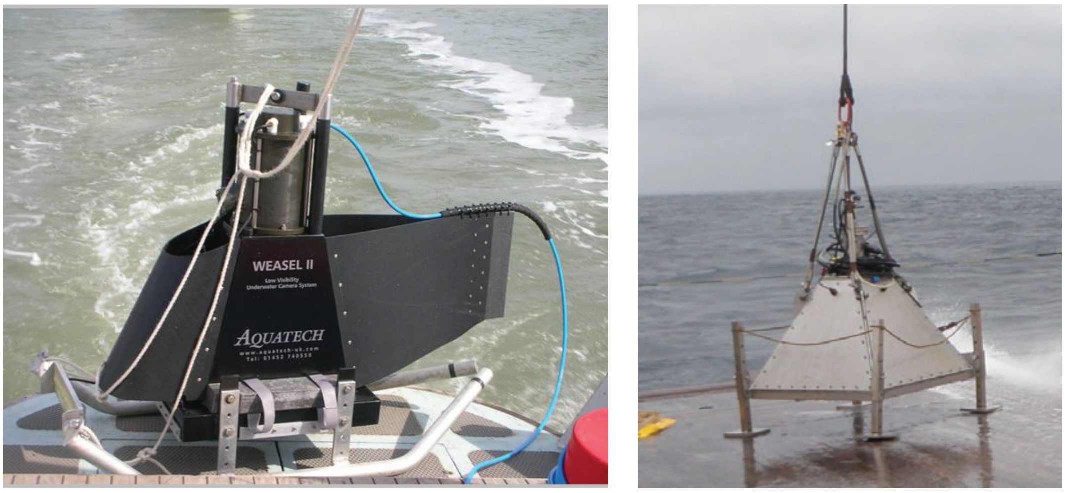


Figure 11. Examples of camera systems incorporating a freshwater lens. Reproduced by kind permission (MES Ltd 2009).

Quality Assurance

There exists a dedicated Quality Assurance protocol for analysing data gathered from underwater video surveys (NMBAQC[4]). Practitioners and analysts of optical surveys are strongly recommended to participate in such schemes to ensure a consistent and standardised proficiency in analysing video and stills data.

A3.2 Grabs and Corers

Introduction

A wide variety of tools are available to sample the substrate and/or its inhabitants at the seabed (see Eleftheriou and McIntyre, 2005). The choice of which tool to use is usually determined by the nature of the substrate to be sampled (i.e. its hardness/compactness, grain, topology), the organisms targeted for collection, sensitivity or fragility of the habitat to be sampled.

4 www.nmbaqcs.org

Generally, samples from the seabed are obtained by dropping grabs or corers. Each device has attributes which favour certain sampling conditions for improved performance; therefore there is no one device suited to all circumstances. The type and quality of data that can be obtained is also affected by the choice of methodology and must be taken into consideration at the time of planning a survey.

For example, grabs sample a fixed area of sediment from the seabed, allowing a quantitative evaluation of the resident infauna and epifauna. Their relatively small size and mode of action, however, means that they do not effectively sample the larger, and less frequently encountered epifaunal species, or those capable of rapid avoidance reactions. Nor are they suitable for hard, compacted or impenetrable substrates. In addition, when sampling coarse-grained sediments, the closing mechanisms can get jammed by stones, potentially rendering the sample invalid.

This section describes the gear types most commonly used for the environmental assessment of aggregate extraction sites, taking into consideration the types of sediment usually encountered. For descriptions of gear types not covered by this section the reader is referred to Eleftheriou and McIntyre (2005) and DTLR (2002).

Equipment

A range of grabs typically employed for surveys of marine aggregates is given in Table 4.

Table 4. Description of grabs used for the collection of sediment samples from the seabed.

Sampling Device	*Surface Area Sampled*	*Approximate Weight (no sample)*	*Suitable for coarse sediments*
Mini-Hamon Grab	0.1 m^2	300 kg (+ weights up to 300 kg)	Yes
Day Grab	0.1 m^2	80 kg (+ weights up to 80 kg	No
Small van Veen Grab	0.1 m^2	80 kg	No
Costerus Grab	2 x 0.1 m^2	400–480 kg	Yes
Shipek Grab	0.04 m^2	80 kg	Yes (not suitable for faunal assessment)

The Mini-Hamon Grab

The mini-Hamon grab (Oele, 1978; Eleftheriou and Moore, 2005) is the gear that is most frequently employed for the collection of sediment samples in coarse sediments. It consists of a rectangular frame forming a stable support for a sampling bucket attached to a pivoted arm (Figure 12). On reaching the seabed, tension in the wire is released which activates the grab releasing the arm to pivot freely. Tension in the wire during hauling moves the pivoted arm through a rotation of 90°, driving the sample bucket through the sediment. At the end of its movement, the bucket opening presses onto an inclined rubber-covered steel plate, sealing it completely. The mini-Hamon grab is robust, simple to operate and has been shown to be particularly effective on coarse sediments. Because 0.1 m^2 is the surface area unit employed in most benthic surveys of continental shelf sediments, and conformity with this size allows direct comparison of results with those from a wide array of other sources using a range of other sampling devices, the mini-Hamon grab is the preferred sampler for collecting samples of the benthic infauna in a cost-effective manner.

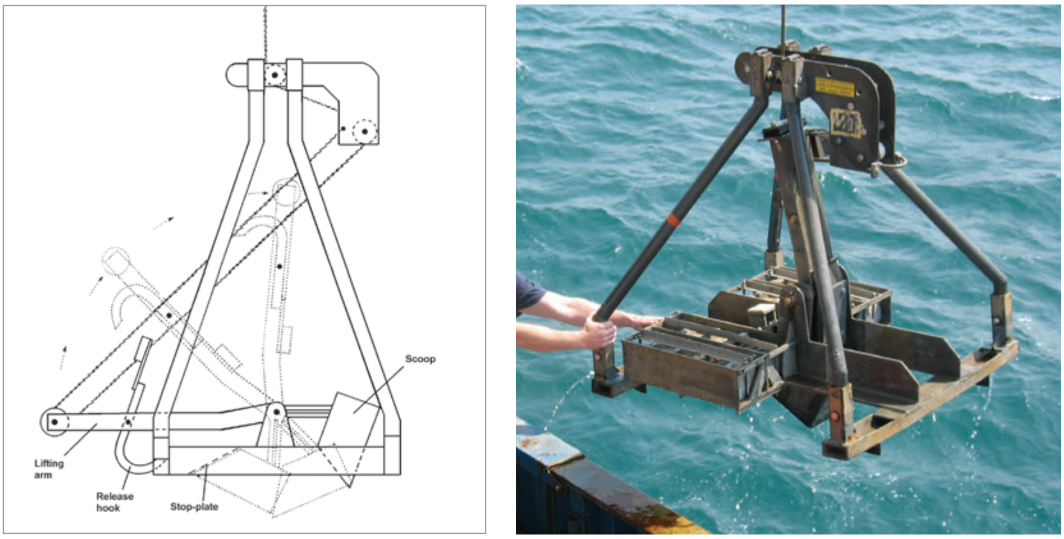


Figure 12. Mini-Hamon grab, showing mode of action (left) and on deck in cocked position (right). Schematic from Eleftheriou and Moore (2005).

The Day Grab

The Day grab evolved from the spring-loaded Smith-McIntyre grab (see Holme and McIntyre, 1984), and represents an attempt to simplify this earlier type of sampling device, without loss of operational efficiency. It incorporates a frame to keep the grab level on the seabed and two trigger plates to activate the release, but there are no springs to force the hinged buckets into the bottom. This device samples an area of 0.1 m^2, to a maximum depth of 14 cm. The jaws are supported within an open framework, which will cause minimal down-wash as it lands on the seabed (Figure 13). Lead weights are usually added to obtain optimum penetration of the sediment. The grab should not be allowed to bite too deeply into the sediment as this results in the sediment surface making contact with the closing flaps of the sample bucket, which can ultimately lead to loss of material on retrieval and disturbance of the surficial layers. The jaws of the grab and the flaps on top should seal well to ensure no loss of material when the grab is retrieved. This grab was designed for sampling soft sediments i.e. ranging from sands to muds. It does not function well on coarse sediments due to the tendency of larger particles to prevent closure of the buckets, causing loss of sample and is therefore not well suited for use at aggregate dredging sites. However, where there is a high percentage of soft sediment (sands or muddy sands) associated with a gravelly component, this grab could be used, albeit with the likelihood of a relatively high failure rate.

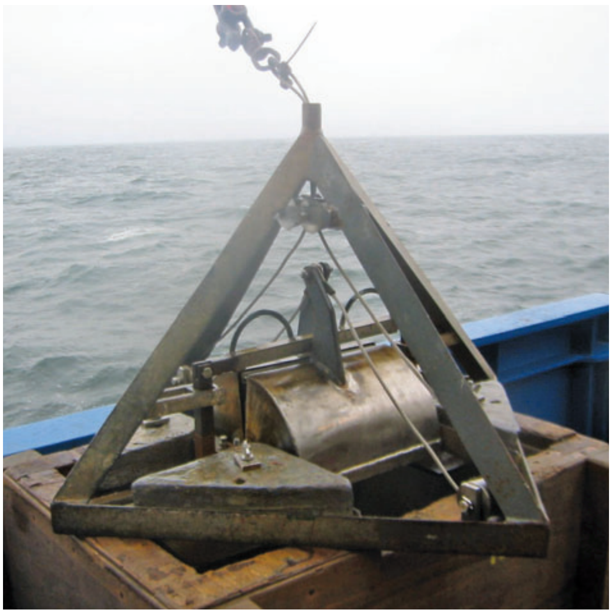


Figure 13. Day Grab (Cefas © Crown Copyright 2011).

Costerus Twin Grab

The Costerus twin grab was recently developed with the aim of improving the quality and efficiency of seabed sediment sampling, particularly in coarser sediments (MEPF 08/P18)[5], whilst maintaining compatibility with existing datasets obtained using samplers such as the mini-Hamon grab. The new grab takes two independent 0.1 m^2 samples at each deployment, one of which can be used for physical and chemical analysis of the sediment and the other for faunal abstraction. The samples are taken in the manner of the mini-Hamon grab but in order to minimise failed deployments the scooping action of the grab is entirely independent of any pulling action of the winch cable. Instead, a compressed air reservoir (a diving cylinder charged to 50 bar) is mounted within the grab body (Figure 14). After the grab settles on the seabed, slack in the cable triggers two pneumatic actuators which force the two sampling buckets through the sediment until they press on the fixed closing plates, scooping the sediment within a few seconds. Once the samples are secured (3-5 seconds) the grab can be hauled up at speed.

Changing the position of the feet allows adjustment of the sampling depth and volume to suit requirements. A reservoir pressure of 50 bar allows some 6 to 12 deployments depending on water depth and the nature of the sediment, after which it is topped up by a compressor or from a 48 litre, 230 bar cylinder of air or Nitrogen.

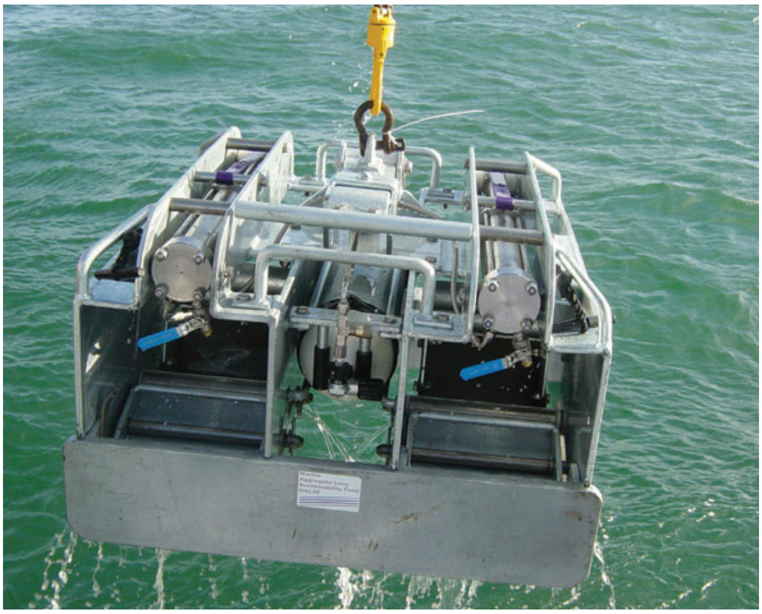


Figure 14. Costerus pneumatic twin grab (MALSF © Crown Copyright 2011).

A compatibility comparison study between the Costerus and mini-Hamon grabs was undertaken in 2009 and is now available on the MALSF website (Barrio Froján and Mason, 2010).

Corers

A number of corers have been designed for the collection of sediments and their resident infauna (see Eleftheriou and McIntyre, 2005). On coarse or consolidated sediments many corers will have a low sampling efficiency, as coarse sediment particles prevent penetration of the device and hinder the proper sealing of the core barrel. Therefore, such devices are not appropriate for routine surveys of marine aggregate extraction sites. However, devices such as vibrocorers may be appropriate for collecting samples from coarse substrates to evaluate vertical structure and integrity of the sediment. Vibrocorers are widely used by industry in prospecting surveys, so information relevant to initial survey planning and design may be available.

5 Coppock, J., 2009. Research, development, production and evaluation of innovative grab sampling devices with a view to improving the quality and efficiency of sea-bed sediment sampling.

A3.3 Trawls and Dredges

Introduction

Towed gears (e.g. trawls and dredges) are more appropriate for sampling epifauna over any terrain, although usually at the expense of accurate quantification due to the unavoidable variability in their usage. For this reason, the overall aims of a survey should be taken into consideration when selecting the most appropriate sampling equipment and, in certain situations, it may be necessary to use more than one gear type in order to sample the full range of benthic organisms present in an area for the purposes of characterisation. Additionally, before employing a given towed gear consideration should be given to the scientific value of the data obtained in relation to the risk of damaging potential features of conservation importance (e.g. biogenic reef).

A range of semi-quantitative trawls and dredges that are suitable for deployment in a range of sediment types are detailed in Table 5.

Table 5. Description of trawls and dredges used for collection of semi-quantitative epifaunal samples

Sampling Device	*Surface Area Sampled*	*Approximate Weight (no sample)*	*Suitable for coarse sediments*
2 m Beam Trawl	Variable	60 kg	Yes
Anchor Dredge	Variable	65 kg	Yes
Rock Dredge	Variable	140 kg	Yes

2 m Beam Trawl

The 2 m Beam Trawl is routinely employed for the collection of epifaunal samples from a variety of sediment types. The trawl consists of a metal or wooden beam, a chain mat designed to prevent the collection of larger boulders, and chafers to limit damage to the net; the net itself consists of a belly (98 rows m^{-2}) and codend (157 rows m^{-2}), with a 3 mm mesh codend liner to capture smaller organisms (Jennings *et al.*, 1999; Figure 15). The 2 m Beam Trawl is designed to sample at and just above the surface of the seabed. Its small size makes it easy to deploy and usually results in the collection of a manageable sample size. For these reasons it is recommended for sampling the epifauna at marine aggregate extraction sites for the purposes of characterisation.

Figure 15. 'Jennings' 2 m Beam Trawl with metal beam (Cefas © Crown Copyright 2011).

On each deployment, 2 m Beam Trawls should be towed over a distance which will collect a sufficiently large sample to adequately characterise the resident epifaunal assemblage, but not so large that the sample is unmanageable. Typically, the trawl is towed across a pre-determined range ring to allow the direction of travel to be decided according to prevailing tidal direction.

A speed of 1-2 knots over the ground is recommended. It is essential that information on tidal state and weather conditions are recorded, as they may contribute to observed differences between stations and/or sampling times.

The gear is lowered ('shot') over the stern and the winch is 'veered' (cable is paid-out) to a distance equivalent to approximately three times the depth of water. When nearly all the cable ('warp') has been paid-out, the vessel slows down to the nominal towing speed (1-2 knots). Further guidance can be found in the 'Recommended operating guidelines (ROG) for MESH trawls and dredges' (Curtis and Coggan, 2006).

A4 Sediment and Faunal Sample Processing & Analysis

A4.1 Sediment and Faunal Sample Processing

Introduction

For convenience, the process of separating organisms from sediments or, in the case of trawls and dredges, other residual material is usually separated into two stages. Initially, collected samples are processed by tipping them over sieves of appropriate mesh size onboard the survey vessel in order to reduce the bulk of the material transported back to the laboratory. The retained material is fixed immediately, allowing for the final separation of the fauna from the residue to be done in the laboratory at a later stage. In cases where, for logistical reasons, it is impractical to process samples onboard the survey vessel (e.g. due to restricted deck space or limited numbers of personnel), entire samples may be preserved in the field and dealt with on return to the laboratory. This section briefly describes the treatment of benthic samples obtained using grabs, trawls and dredges.

Processing Semi-quantitative Epifaunal Samples From Trawls and Dredges

On retrieval of the trawl, the catch should be concentrated in the cod-end of the net. The contents of the cod-end should be released into suitable sample containers and an estimate made of the total volume of the catch including a photograph should be taken. It is essential that all the fauna is retrieved from the full length of the net and included in the analysis of material.

Figure 16. Volume of a beam trawl sample being measured using a graduated bucket before being washed and sorted over a 5 mm mesh screen (Cefas © Crown Copyright 2011).

Epifaunal trawl samples often require sub-sampling in order to manage the large number of organisms encountered. Further guidance on sub-sampling procedures can be found in the Recommended Operating Guidelines (ROG) for MESH trawls and dredges (Curtis and Coggan, 2006).

Samples should be processed over a frame-supported 5 mm mesh (Figure 16), discarding any material passing through the mesh. Counts of very abundant solitary species may be derived by sub-sampling. Colonial species (notably hydroids and bryozoans) are generally recorded on a presence/absence basis.

Whilst the processing of trawl samples typically involves the identification and enumeration of the faunal component of the sample a number of additional data may be required under certain circumstances and these may include length frequency data for commercially important fish and shellfish species, biomass, analysis of cobbles and attached fauna.

Processing Quantitative Samples Collected by Grabs

Estimation of Sample Volume

On retrieval of a grab an estimate of the sample volume should be made following its release into a container, along with a description of the sediment type. With a mini-Hamon grab sample, an estimate may be made following its release into a container of known volume.

In some instances it may be necessary to reject grab samples; the following criteria should be applied to all samples:

1. **Sample inspection** – if the jaws of the grab are not fully closed (e.g. due to the presence of stones in the mechanism) and there is associated evidence of the winnowing of surface material, then the sample should be rejected. Rejected samples should still be logged (along with the position from which they were obtained). Such information is important in informing any subsequent survey designs and ensuring the choice of gear is suitable for the substrate known to be present.
2. **Acceptable sample volume** – for the mini-Hamon grab, the aim should be to collect a minimum sample volume of 5 litres, and samples smaller than this would normally be rejected. However, in very coarse substrates, the failure rate may be very high, and expert judgement should be exercised regarding the collection of the occasional sample of less than 5 litres. The reasoning behind this judgement should be documented in the survey log and in any subsequent reports, and the sample(s) flagged on account of their failure to meet the above quality criterion.
3. The pooling of failed samples should never be undertaken.

Separation of Infauna from the Sediment

Sediment samples should be carefully released into appropriately sized sample containers, ensuring there is no spillage of material. Once it has been determined that an acceptable sample volume has been obtained the whole sample is photographed and a sub-sample for sediment particle size analysis is taken (see Section A4.3). Separation of fauna from the sediment may be achieved by transferring the sample to a purpose-built sieving table to be washed with seawater (under gentle hose pressure) over a removable 5mm square mesh sieve, capturing the residual material over a 1 mm mesh sieve as shown in Figure 17. A range of methods and equipment for washing and sieving sediment samples is available and these have been reviewed by Eleftheriou and Moore (2005) and Proudfoot *et al.* (2000).

Figure 17. Labelled macrofaunal grab sample (right) awaiting processing (left) using a purpose built sieving table. The sample is being washed over a 5 mm square mesh aperture sieve supported by a removable square stainless steel frame. Note also the 1 mm mesh sieve held within a sieve holder beneath the outlet pipe of the table (Cefas © Crown Copyright 2011).

Accumulations of fine sediment on the mesh can usually be removed by gentle 'puddling' involving vertical motions of the sieve in a seawater-filled container. Horizontal or circular movements of the sieve should be avoided as this can result in damage to the fauna through abrasion against the sieve. A number of additional steps are required when processing samples at sea, namely:

Washing the Equipment

Equipment must be washed down between samples so as to avoid cross contamination.

Transfer of Processed Material to Sampling Containers

Material retained on the sieves should be backwashed with seawater into suitable containers using a funnel.

Sample Preservation

Biological material will require initial fixing with a solution of formaldehyde. Fixation hardens the tissues and reduces the chances of damage or breakage of the specimens, as well as preventing decomposition. For effective fixation the sample should be submerged in buffered formaldehyde solution at a final concentration of 4-5%. Samples should be stored in the fixative for a minimum of three days before any further processing takes place (Gray *et al,* 1992; Eleftheriou and Moore, 2005). Appropriate CoSHH and risk assessments should be undertaken using the manufacturers Material Safety Data Sheet (MSDS).

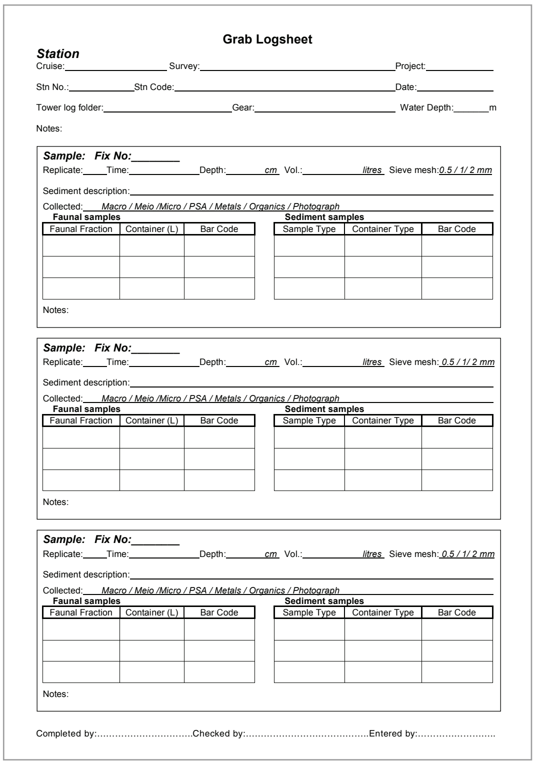
Once samples are fixed, alcohol (70% ethanol/Industrial Methylated Spirit) is used for long-term preservation of samples, but it should not be used during initial field preservation. Further information on the use of fixatives, preservatives and buffering agents is provided by Lincoln and Sheals (1979).

Sample Labelling

Labels should be applied to both the outside and the inside of any sample container. The internal label should be waterproof, chemically resistant and annotated with a soft-carbon pencil or permanent marker which will not fade in formaldehyde.

Sample Logging

All surveys should be logged in a pre-designed field log or electronic datasheet. Each log-sheet should contain prompts for all the information required (see MEDIN data guidelines for details[6]). It may also be useful to offer a list of options for recording certain variables (e.g. sediment type), to improve objectivity. An example of a Cefas grab sample log sheet is shown in Figure 18.



Grab Logsheet

Station

Cruise:________ Survey:________ Project:________

Stn No.:________ Stn Code:________ Date:________

Tower log folder:________ Gear:________ Water Depth:______m

Notes:

Sample: Fix No:________

Replicate:_____ Time:________ Depth:______ *cm* Vol.:________ *litres* Sieve mesh: *0.5 / 1/ 2 mm*

Sediment description:________

Collected: *Macro / Meio /Micro / PSA / Metals / Organics / Photograph*

Faunal samples

Faunal Fraction	Container (L)	Bar Code

Sediment samples

Sample Type	Container Type	Bar Code

Notes:

Sample: Fix No:________

Replicate:_____ Time:________ Depth:______ *cm* Vol.:________ *litres* Sieve mesh: *0.5 / 1/ 2 mm*

Sediment description:________

Collected: *Macro / Meio /Micro / PSA / Metals / Organics / Photograph*

Faunal samples

Faunal Fraction	Container (L)	Bar Code

Sediment samples

Sample Type	Container Type	Bar Code

Notes:

Sample: Fix No:________

Replicate:_____ Time:________ Depth:______ *cm* Vol.:________ *litres* Sieve mesh: *0.5 / 1/ 2 mm*

Sediment description:________

Collected: *Macro / Meio /Micro / PSA / Metals / Organics / Photograph*

Faunal samples

Faunal Fraction	Container (L)	Bar Code

Sediment samples

Sample Type	Container Type	Bar Code

Notes:

Completed by:.................... Checked by:.................... Entered by:....................

Figure 18. Example of a Cefas grab sample log sheet.

A4.2 Laboratory Processing of Grab Samples for Faunal Analysis

Elutriation and Sorting

Before any processing takes place, the formaldehyde fixative must first be washed out from a sample and disposed of appropriately. This process must be carried out with adequate ventilation and protective clothing. Organisms are then sorted and removed from the sample through a combination of elutriation and hand picking using suitable equipment (Figure 19).

Figure 19. (left) Gridded tray containing sorted sample. Note the illuminated magnifier. (right) Binocular microscope being used for specimen identification (Cefas © Crown Copyright 2011).

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6 www.oceannet.org/marine_data_standards/medin_approved_standards/documents/medin_sediment_benthos_3_1_15july10.pdf

Identification and Enumeration

All specimens of solitary taxa should be identified down to the lowest possible taxonomic level, usually species, using standard taxonomic keys, and enumerated. Taxonomic nomenclature should be compliant with the World Register of Marine Species (WoRMS[7]). Only specimens with an anterior end are counted. Distinction should be made between adult and juvenile specimens where possible. Colonial species (e.g. hydroids and bryozoans) are usually recorded on a presence/absence basis.

Biomass Determination

If biomass estimates are required, they may be determined as wet weight and then converted to Ash Free Dry Weight (AFDW) using standard conversion factors (e.g. Rumohr *et al.* 1987; Ricciardi and Bourget, 1998 and Eleftheriou and Basford, 1989).

Sample Re-analysis (QA)

A random selection of 10% of the samples processed should be re-analysed for QA purposes. Guidelines are provided by the UK NMBAQC[8]. The outcome of QA/QC activity should be included in any reporting of the data.

Sample Tracking

Sample tracking (i.e. information concerning the location and status of samples at all stages following collection) is an essential part of any Quality Assurance programme.

Preservation and Storage

Specimens from each sample should be transferred to a single container, and a preservative solution of 70% ethanol/IMS applied.

Reference Collections

For QA purposes it is good practise for laboratories engaged in faunal sample processing and identification to maintain an 'in-house' reference collection which contains at least one example of all species encountered.

A4.3 Collection and Analysis of Sediment Samples for Particle Size Analysis (PSA)

Field survey methods and laboratory procedures for assessing seabed sediment particle size distributions are currently being evaluated by the National Marine Biological Analytical Quality Control Scheme (NMBAQC) (see Mason, in prep, 2010).

Field Sub-sampling Sediment for Particle Size Analysis from a Macrofaunal Sample

After the contents of the grab have been emptied into a sample container, it is important that the subsample which is removed for PSA is as representative of the whole sample as possible. Typically, when using a 0.1 m^2 mini-Hamon grab, a sub-sample of approximately 500 ml is removed using a plastic scoop. The PSA sample should, where possible be stored frozen in a sealed container, preferably in the dark, prior to later laboratory analysis.

Laboratory Splitting the Sample into a Coarse and Fine Fraction

The whole sample should initially be wet sieved on an automated sieve shaker (Figure 20) using a 500 µm sieve if optical techniques, such as laser diffraction, are to be used for the analysis of the finer fraction, or a 63 µm sieve if settling techniques/optical techniques are to be used.

7 www.marinespecies.org

8 www.nmbaqcs.org/media/9732/nmbaqc%20-%20inv%20-%20prp%20-%20v1.0%20june2010.pdf

Figure 20. The automated wet sieve shaker is used to split a sediment sample into a coarse fraction and fine fraction. The coarse fraction remains on the sieve, and the fine fraction passes through the sieve to be retained in a collecting pan. The two fractions may then be treated separately for further particle size analysis (Cefas © Crown Copyright 2011).

Analysis of the Coarser Fraction Using a Dry Sieving Process

The oven-dried coarser fraction is sieved on a double gyratory jolting sieve shaker (e.g. Pascall Inclyno) using a stack of sieves nested at 0.5 ϕ intervals for a period of 10 minutes. A collecting pan at the bottom of the stack retains the fraction passing through the finest sieve and the weight of the sediment in each sieve should be recorded including the bottom pan.

Analysis of the Finer Fraction

The fine fraction of the sediment should be either freeze-dried, air-dried or oven-dried at a low temperature (<30°C) before sample analysis using either settling techniques such as pipette and Sedigraph® analysis or optical methods such as laser diffraction (Figure 21).

Figure 21. Malvern Mastersizer 2000 laser sizer. This equipment uses laser diffraction technology to measure particle diameters. It is most frequently used to measure the finer component (<63 µm) of a sediment sample (Cefas © Crown Copyright 2011).

Particle Size Data Reporting

The data generated from the analysis of both the coarse and the fine fractions can be combined to produce a complete particle size distribution for each sample, which can then be plotted. When the full distribution has been constructed the sample should be assigned a description based on the Folk classification system (Folk, 1974) and/or the Wentworth classification system (Wentworth, 1922). Statistics relating to particle size distributions can be calculated and described using the formulae given in Dyer (1986), using Gradistat, an Excel based programme (Blott and Pye, 2001).

Quality Control Procedures

The use of certified reference material to check the performance of laboratory equipment is recommended. Additionally, the use of an internally produced standard sediment is another valuable method of checking equipment on a more frequent basis. Subscription to accredited QC schemes, such as the NMBAQC Scheme and the Particle Analysis and Characterisation Scheme (PACQS), co-ordinated by the Laboratory Government Chemist (LGS), is recommended. BS1377 also lists recommendations for laboratory apparatus specifications and calibrations which are valuable for checking analytical performance.

ANNEX B

Data

The principal objective of any investigation into the effects of aggregate extraction on the benthic environment is to amass a weight of evidence, through the appropriate assessment of monitoring data, that allows transparent and accountable decision-making during the regulatory process. More specifically, hypotheses are formulated and tested based upon the monitoring and assessment objectives, for example:

- the identification of spatial pattern in the macrofaunal assemblage and its relationship with environmental conditions (using baseline/exploratory data);
- the detection and quantification of the effects attributable to aggregate extraction, and the identification of other influencing factors (using ongoing monitoring data);
- the monitoring of macrofaunal recolonisation of aggregate extraction sites following the cessation of dredging until a stable state is demonstrated (using post-extraction data).

B1 Data Manipulation

There are a number steps that can be taken to reduce the amount of variability in a dataset, as well as to simplify and standardise the underlying structure of the dataset (i.e. the associated metadata) for ease of manipulation. Each of these steps is considered in turn:

B1.1 Truncation

Truncation is the process of identifying and reducing the incidence of spurious taxonomic identifications, which is a particularly important process when combining datasets from different surveys. It is important to know how to recognise identifications that are genuinely spurious, as well as to keep a detailed record of why and how taxa have been truncated (i.e. by merging or deletion).

B1.2 Metadata

Metadata are additional pieces of information associated with each sample. Such information can include the date and time of sampling, positional information, reference to whether samples are replicates or from a particular treatment, a sediment descriptor, a survey label, etc.

B1.3 Traits

Information on species' traits is becoming more widely available (e.g. Marine Macrofauna Genus Trait Handbook[9], Interactive Genus Trait Handbook[10] & Biological Traits Information Catalogue (BIOTIC)[11]). Characteristics or trait information may be assigned to the species represented in the abundance matrix and these may include morphological traits (i.e. size, body form etc.), ecological traits (i.e. living location, mobility, feeding method) or reproductive traits i.e. reproductive method, egg/larval/juvenile position etc.). This allows a number of 'trait based' analyses to be applied to further assess the significance of observed structural changes in the faunal assemblage on their capacity to provide given functional roles or ecosystem services.

9 www.seasurvey.co.uk/sites/default/files/docs/Print_HANDBOOK.pdf

10 www.genustraithandbook.org.uk

11 www.marlin.ac.uk/biotic

B1.4 Integration of Historical Datasets

Combined survey datasets should be checked for taxonomic consistency (and truncated accordingly), equivalence of sampling units, seasonal variations, pseudoreplication, and whether the data violate any assumptions imposed by the statistical tests intended to test for pattern.

B1.5 Environmental Data

Environmental data can be analysed in similar ways to biological data, as each sample should have a suite of associated values, each pertaining to a different environmental variable that has been measured. As with biological data, environmental data can also have associated metadata, which enable further data manipulation where necessary.

B2 Data Analysis

Statistical methods used for describing assemblage structure can be grouped into three categories: univariate methods, distributional techniques and multivariate methods (Figure 22). For each of these categories, appropriate statistical tests have been developed to determine the significance of differences observed between samples.

For convenience, emphasis in the following guidance is placed on statistical routines that are included in the PRIMER (Plymouth Routines In Multivariate Ecological Research) software package developed at the Plymouth Marine Laboratory (Clarke and Warwick, 1994; Clarke and Gorley, 2006). This is because the package is widely employed and has gained general acceptance as a tool for analysing benthic datasets. However, it is also recognised that there are many other software packages and statistical techniques which are equally suited to the task of handling benthic datasets, such as CANOCO (Jongman *et al.* 1987), TWINSPAN and DECORANA (Hill, 1979). It should be noted that both novel statistical approaches for the analysis of biological data and new statistical software packages are continually emerging.

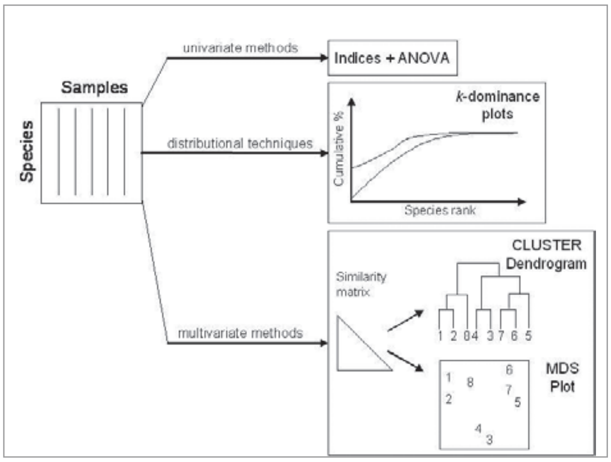


Figure 22. Statistical methods used to analyse macrobenthic assemblage structure (adapted from Schratzberger, 1998).

B2.1 Distributional Techniques

Diversity profiles of a sampled assemblage can be visualised by plotting *k*-dominance curves (Lambshead *et al.* 1983). The purpose of such curves is to extract information on the dominance pattern within a sample, without reducing the information to a single summary statistic, such as a diversity index. Species counts and biomass data can be summarised in abundance-biomass curves (ABC) applying the *k*-dominance procedure (Warwick, 1986). A strongly disturbed state is indicated if the abundance curve is plotted above the biomass curve throughout its length.

Where biomass data are only calculated for lower taxonomic levels (e.g. Phyla) it is not possible to plot an ABC curve. In practise, dominance curves are typically employed (as shown in Figure 23) to assess the relative percentage contribution of given species to overall abundance by ranking the species (along the x axis) and plotting their cumulative percentage contribution to the overall abundance on the y axis.

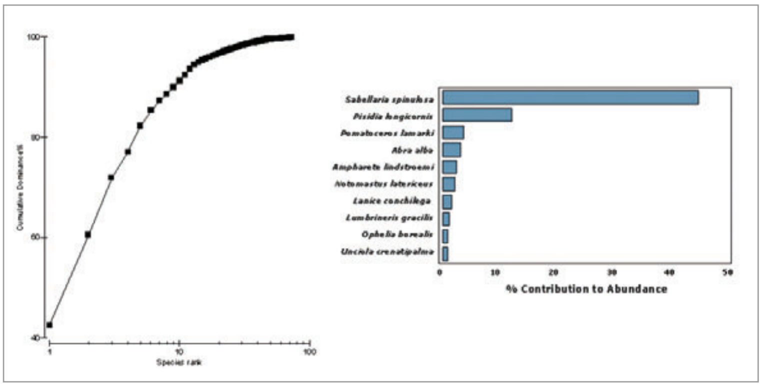


Figure 23. Dominance curve plotted for cumulative percentage contribution of ranked species (Copyright MES Ltd. 2009).

B2.2 Univariate Methods

Univariate statistical analyses test the distribution of a single variable at a time (as opposed to the distribution of several variables at a time – i.e. multivariate). The latest PRIMER software package allows the calculation of more recently-developed biodiversity indices, such as the taxonomic diversity and distinctness indices. These indices capture the taxonomic relatedness of species within each sample and have the important attribute that they are not overly dependent on sampling effort, implying that results can be compared directly across studies with differing degrees of sampling effort (Clarke and Warwick, 1999).

Values for univariate measures can, in practise, be effectively displayed in a number of ways, to assist in the elucidation of spatial patterns and further investigate the relative contribution of given faunal groups to the overall assemblage. For example, Figure 24 shows the spatial gradient in species number, abundance and biomass.

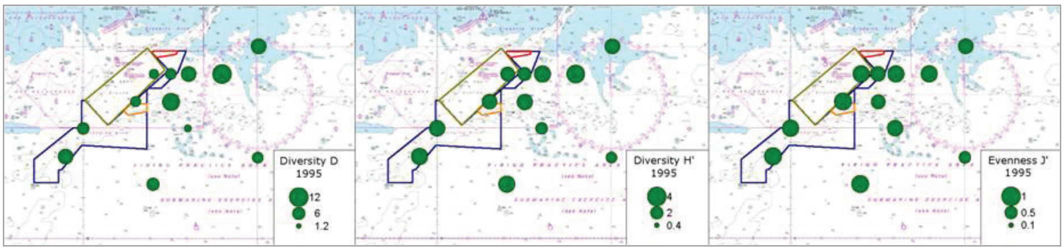


Figure 24. Spatial distribution of univariate indices as typically presented in an EIS (Copyright MES Ltd. 2009).

B2.3 Summary Statistics and Tests of Significance

When information in a sample is reduced to a single variable or index, the existence of replicate samples from different treatments allows formal statistical parametric testing by analysis of Variance (ANOVA). The use of parametric tests are only appropriate where data conform to the assumptions of parametric testing (i.e. data are normally distributed and of equal variance) though it should be noted that ANOVA is more robust to departures from normality and homogeneity of variance where the survey design is balanced (i.e. sample sizes are equal across the treatments). The most commonly encountered design for marine aggregate EIAs is a two-way design and these have two factors to consider in the analysis, namely; time and dredging impact. Time has an increasing number of levels which increases with each survey. Impact has 3 levels: namely PIZ, SIZ and Reference. The null hypothesis being tested is that each set of data from the different treatments has the same mean. A significant result in the ANOVA (i.e. P value <0.05) will show that at least one pair of the treatments being tested is statistically different (see Underwood, 1997).

Many other statistical tests exist, which may be more appropriate than ANOVA, depending on the questions asked and the type of data used. For example, Permutational Multivariate Analysis of Variance (PERMANOVA) (Anderson *et al.* 2008) can be utilised to test for significant differences in univariate parameters, such as between factors, groups or treatments. In addition, due to its permutation based approach, it is not constrained by the assumptions of normality and homogeneity of variance associated with parametric approaches.

B2.4 Multivariate Methods

A number of multivariate techniques may be applied to benthic datasets to determine whether assemblages respond to different types of disturbance by small but consistent changes in the relative abundance of species which are unlikely to be detected by comparisons using univariate indices. A thorough understanding of the rationale behind multivariate analytical routines is of paramount importance to ensure that the true signal is extracted from the data. Multivariate measures of similarity are typically employed in practise to:

1. Elucidate spatial patterns in faunal assemblages for the purposes of characterisation (and these may subsequently be compared with multivariate patterns in associated environmental data to assess which physical parameters best describe the observed faunal trends).
2. During ongoing monitoring to identify the presence (and magnitude) of any differences in faunal assemblages between the pre-assigned treatments (i.e. PIZ, SIZ and reference sites) that may be attributable to the dredging activity.

A number of **manipulations** may be applied to the data before carrying out any analyses and these may include:

1. Transformation: the process of 'downgrading' the influence of the most abundant species, which may overwhelm any underlying pattern in the dataset.
2. Addition of a 'dummy variable': a 'dummy variable' may be added to the data to ameliorate the double zero problem when creating your resemblance matrix (using Bray-Curtis or other similarity coefficients). Adding a 'dummy variable' also reduces the influence of samples that have very low similarity with the rest (e.g. outliers).

Measuring the Similarity of Species Abundance and Biomass between Samples

Similarities between sets of samples may be explored by constructing a similarity matrix using a similarity coefficient that is most 'fit for purpose' for your data set. In the case of biological datasets the Bray-Curtis similarity coefficient is typically employed due to it exhibiting a number of desirable criteria (Clarke and Warwick, 1994). These are given as:

1. When two samples are identical it takes the value of 100.
2. When two samples have no species in common it takes the value of 0.
3. A change of measurement unit does not affect its value.
4. Its value is not affected by inclusion or exclusion of a species which is jointly absent from two samples.
5. Inclusion (or exclusion) of a third sample C does not affect the similarity between samples A and B.
6. It has the flexibility to detect differences in total abundances between two samples even when their relative species abundances are identical.

Grouping of the Data

A number of methods exist for grouping data where no 'a priori' groups have been assigned. Figure 25 shows an example of a dendogram, produced using hierarchical clustering, with 'true' groupings defined using SIMPROF. Similarity Percentage (SIMPER) can subsequently be employed to determine which species are responsible for discriminating between the clusters.

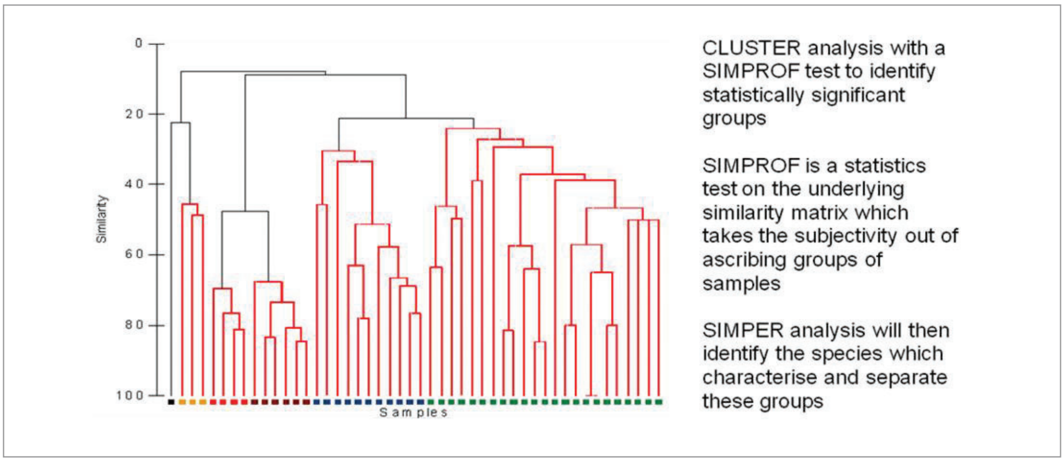


Figure 25. Dendogram produced using hierarchical clustering with 'true' groups defined using SIMPROF (Copyright MES Ltd. 2009).

Ordination

Ordination is employed to construct a configuration of samples which attempts to plot all the information contained in the underlying similarity matrix in either a 2d or 3d spatial representation. In practise multi-dimensional scaling techniques are typically employed to produce plots which illustrate the configuration of samples in the multidimensional space.

Permutation Based Hypothesis Testing (e.g. ANOSIM, PERMANOVA): Routines for Detecting Structure in 'a Priori' Structured Samples

Analysis of Similarity (ANOSIM) is typically employed to test for significant differences between groups of samples (that have been assigned 'a priori'). ANOSIM is a permutation based test which compares the differences between groups with differences among replicates within a group. The resulting test statistic or R value =1 where all replicates within a predetermined group are more similar to each other than any replicates from different groups. Conversely, R is approximately zero where the null hypothesis is true and between and within site similarities are the same.

A global ANOSIM test should initially be carried out as this takes into account the total number of replicates, and thus allows a high number of possible permutations, which results in a highly reliable and informative test. Where the global test indicates that differences exist that may be worth exploring further specifics pairs of groups can then be explored. However, caution should be applied in interpreting the resultant test statistic (and its associated significance level) where low levels of replication exist. For example, an ANOSIM based on three replicates within each group will only allow 10 distinct permutations; a significance greater than 10% could never be attained. Therefore, the general rule is that the power of detection will improve with increasing replication and low levels of replication should be avoided altogether when designing a survey.

PERMANOVA employs resemblance and permutation based methods to analyse univariate or multivariate data in the context of more complex experimental designs and models. PERMANOVA employs a more parametric approach and partitions variability according to a number of pre-determined factors or explanatory variables between which interactions can be tested. Whilst PERMANOVA can essentially be viewed as a better ANOVA/

MANOVA, in that it allows tests between factors to be carried out, along with tests for interactions between them, but does not require the same assumptions to be met as its parametric counterparts (i.e. data do not have to be normally distributed or have equal variances).

B3 Data Integration and Interpretation

The final stage in any study is the integration of the results with any other available information to allow the best possible interpretation. Survey data, including acoustic, photographic, physical and biological information, can be integrated by entering it directly into a GIS package. Knowledge on the ecology of species and assemblages (e.g. feeding habits, environmental preferences, functional significance), as well as existing maps or distributions of relevant processes (e.g. current speed and direction, tidal flow, thermoclines), can also be included to aid interpretation of the importance of the distribution of species and of their ecological significance which enables us to interpret changes in sediment type and/or environment.

B4 Quality Assurance

Quality Assurance (QA) can be defined as 'all those planned or systematic actions necessary to provide adequate confidence that a product or service is of the type and quality needed and expected by the customer'. Required standards are determined for each stage of a process, with Quality Control (QC) benchmarks put in place to check for satisfactory attainment. Analytical Quality Control (AQC) encompasses procedures which ensure that all measurements are within an acceptable level of accuracy and precision. Guidelines for the establishment of quality control systems are given in Rees (2004), with the emphasis on marine biological studies. Additional information can be found on the Marine Biodiversity and Ecosystem Functioning (MarBEF) website[12].

B4.1 Standard Operating Procedures

One of the most important practical tools in quality assurance is the provision of Standard Operating Procedures (SOP). The European Communities (1999) define SOPs as "documented procedures which describe how to perform tests or activities normally not specified in detail in study plans or test guidelines". SOPs are therefore an integral and essential part of any Quality Assurance programme which help to ensure that data collected by any laboratory that uses them are scientifically valid, comparable and adequate to meet the study objectives. A general guidance for writing SOP's can be found in Appendix 5.

B4.2 Sample and Data Storage

Before processed samples are disposed of, the following should have occurred:

- All fauna contained within samples should have been identified and enumerated.
- Internal AQC procedures should exist and should have been followed (see the NMBAQC's 'Own Sample' exercise for one approach[13]).
- Any 'new' species identified from the given survey should be incorporated into the laboratory reference collection.

Data generated from each survey should be stored on dedicated database systems. These can be developed in-house or existing systems can be used (e.g. UNICORN). It is encouraged that once newly acquired data is no longer needed for the purpose it was collected or it is no longer commercially sensitive, it is placed in one of the national data

12 www.marbef.org/qa/index.php

13 www.nmbaqcs.org/scheme-components/invertebrates.aspx

repositories for archiving. There exists a number of European and national initiatives that promote common metadata standards for the collation of marine environmental metadata (e.g. INSPIRE, UK GEMINI, MEDIN). In addition, there are also centralised archives dedicated to the long-term storage of datasets, known as Data Archive Centres (DAC). Examples include the National Biodiversity Network, for sharing wildlife records; the UKHO, for storing hydrography and navigation data; the BODC, for oceanographic data; DASSH, for species and habitats data; BGS, storing sidescan data; and Cefas, who archive fisheries data. Additional guidelines related to data management and access have been prepared by MEDIN[14]. These data guidelines propose consistent formats for recording data that should be adhered to. This will also improve the transfer of data between organisations and ensure the appropriate archiving of data and information.

14 www.oceannet.org/marine_data_standards/medin_data_guide.html

ANNEX C
Reporting

There are a number of different types of report that will be required at different stages of the regulatory or licensing process. These include:

1. Scoping documents for proposed surveys in support of new licence applications, renewals or subsequent monitoring objectives.
2. Reporting of outcomes of biological surveys in support of an ES at the licence application or renewal stage.
3. Reporting of outcomes of monitoring surveys at agreed time intervals.

C1 Generic Structure for Reporting of Benthic Studies

Title Page

Should include:

- Details of licence areas to which document is relevant.
- What the document type is (i.e. scoping report, benthic ecological impact assessment in support of an ES, monitoring report, etc.).
- Name and contact details of the company that has carried out the benthic study and compiled the report.
- Name of the aggregate extraction company for which the study has been carried out.
- Date that the report was completed (with a record of internal review and QA).

Executive Summary

This section should provide an overview of the rationale and objectives of the study, methods used in meeting the objectives and a brief discussion of the outcomes of the study in relation to the underlying objectives.

Introduction

Should include:

- The purpose of the study.
- Location of the study site.
- A summary of previous dredging history within the licence area under investigation accompanied by a figure illustrating dredging intensity (derived from EMS data) in relation to the location of sampling stations.
- Materials and Methods

This section should include a description of the methods and approaches taken in consideration of the following points:

- A statement of the objectives of the assessment and the hypotheses that are to be tested.
- A statement on the process of scoping to produce an overview of existing information relating to the study area and how this has been used to inform the survey design, to include:
  - Outputs from site specific surveys carried out in support of previous licence applications or renewals (not applicable where the study is in support of a licence application for a previously un-dredged site).

  - Outputs from REA and REC surveys and studies.
  - Site-specific data held by aggregate dredging companies (e.g. acoustic data collected using sidescan or multibeam sonar and sub-bottom profiles). These data can be particularly useful in informing survey design where a stratified approach is adopted, requiring delineation of biotopes within an area.
- Identification of the likely zones of impact (PIZ and SIZ), which may vary during the whole life-span of the project.
- Identification and evaluation of ecological resources, features and functions likely to be affected by the proposal.
- Identification of the drivers of biophysical changes attributable to the project.
- Identification of the biophysical changes attributable to the project that are likely to affect the valued ecological resources and features.
- Assessment of whether these biophysical changes are likely to give rise to a significant ecological impact, defined as an impact on the integrity of a defined site or ecosystem and/or the conservation status of habitats or species within a given geographical area, including cumulative impacts.
- Refinement (if any) of the project to incorporate mitigation measures to avoid or reduce identified negative impacts, and compensation measures for any residual significant negative impacts and ecological enhancement measures to improve the wider environment.
- Assessment of the ecological impacts of the refined project and definition of the significance of these impacts.
- Provision of advice on the consequences for decision making of the significant ecological impacts, based on the value of the affected resource, feature or function.
- Provision for monitoring and following up the implementation and success of mitigation measures and ecological outcomes, including feedback in relation to predicted outcomes.
- Survey design and underlying rationale for the experimental approach.
- Techniques employed for sample collection (including detail of QA/QC measures employed).
- Techniques employed for sample processing (including detail of QA/QC measures employed).
- Techniques employed for data analysis (including relevant references for specific procedures).

Results

- Results should be reported in relation to the pre-determined objectives (and associated hypotheses) as outlined in Section 5.2 and re-iterated above.
- Outcomes of any statistical analyses, and their interpretation, should be reported in full and to be clearly related to the methods and approaches outlined above.
- Relevant figures should be included to illustrate findings and their interpretation should be referred to in the appropriate text.

Discussion

- The discussion should report the outcomes of the study or survey in relation to each of the pre-determined objectives and associated hypotheses.
- Transparency and justification for the interpretation of the results in drawing conclusions, in relation to each of the objectives, is encouraged. This should enable the reader to draw their own conclusions based on the information presented..

References

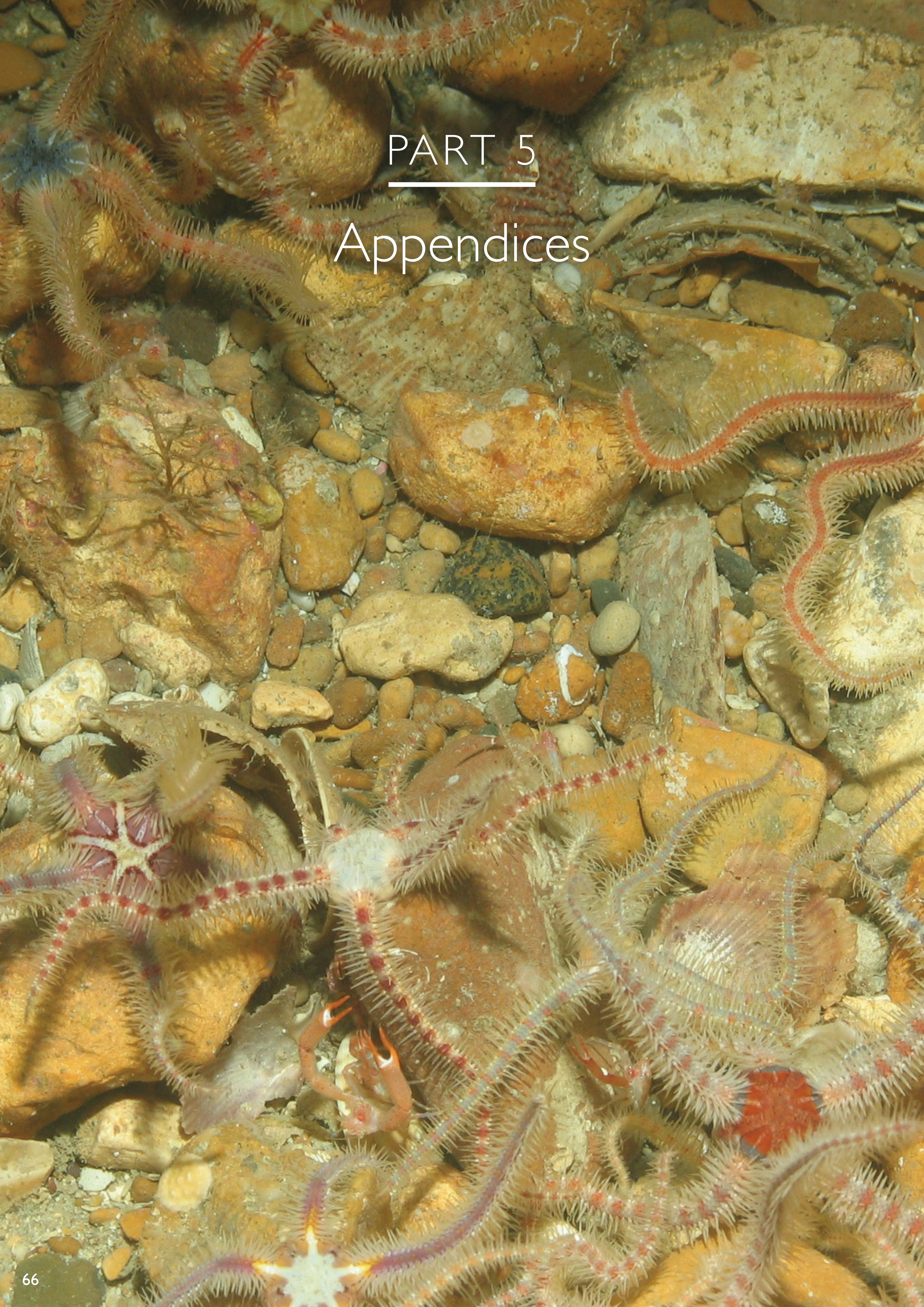
A complete list of cited literature and references should be provided.

Appendices

Any supplementary information in support of any of the decisions and/or conclusions presented in the report should be included in appendices (printed or in digital format).

PART 5

Appendices



APPENDIX I
Glossary of Acronyms and Terms

Active Dredge Zone	A defined zone within a production licence where dredging is permitted to occur
AGDS	Acoustic Ground Discrimination System
AQA/AQC	Analytical Quality Assurance/Analytical Quality Control
Baseline	A survey conducted prior to dredging commencing. The baseline data is used to make a direct comparison with data from subsequent monitoring surveys of the site.
Benthos	Animals and plants which predominantly exist close to, on, or within the substrate of the seabed environment
Biodiversity	Extent of genetic, taxonomic and ecological diversity over all spatial and temporal scales
Biotope	An area of seabed which supports the same characteristic biological and habitat properties. It is a combination of the habitat and the biology which defines a biotope.
Characterisation	A survey whose primary aim is to spatially identify and define the principal boundaries of significant habitat and community features in and around the development area
Cumulative effect	The effects of one type of activity with other types of the same activity (i.e. aggregate dredging and aggregate dredging)
Direct Impact	Impacts resulting from the passage of the draghead over the seabed surface and the associated removal of sediment from the seabed.
Direct Impact Zone	The zone within which impacts resulting from the passage of the draghead over the seabed surface occur
EARS	Environmental Assessment Reference Stations
EIA	Environmental Impact Assessment
EMS	Electronic Monitoring System
ES	Environmental Statement
Epifauna	Organisms living on the surface or in close association with the seabed
GIS	Geographic Information System
GV	Government View
In-combination Effect	The effects of one type of development in combination with other different activities (e.g. aggregate dredging in combination with wind farms or aggregate dredging in combination with shipping)
Indirect Impact	An impact extending beyond the boundaries of a direct impact zone resulting from both the initial settlement and subsequent transport of fine sediment generated by dredging
Indirect Impact Zone	The zone, within and extending beyond the boundaries of a direct impact zone within a licence area, within which impacts resulting from the settlement of fine sediment generated by dredging occur
Infauna	Organisms living within the substrate at the seabed

Lithology	The systematic description of rocks in terms of mineral assemblage and texture
Macrofauna	Benthic invertebrate animals usually retained on a 1 mm mesh sieve
MALSF	Marine Aggregate Levy Sustainability Fund
MFA	Marine and Fisheries Agency
MMO	Marine Management Organisation
Monitoring	A spatially defined survey repeated over time with the purpose of detecting varying levels of changes in ecosystem state and function
PSA	Particle Size Analysis; interchangeable with Particle Size Distribution (PSD)
Primary Impact Zone (PIZ)	The area of seabed which is directly impacted by the action of the draghead causing the direct removal and burial or seabed organisms caused by dredging. This is also equivalent to the direct impact zone.
QA/QC	Quality Assurance/Quality Control
Pseudoreplication	Source of error in the statistical inferences drawn from experiments where groups of interdependent data are mistakenly treated as independent
Rarity	Low in number and restricted to a limited number of locations
REA	Regional Environmental Assessment
REC	Regional Environmental Characterisation
Representativeness	How representative a habitat, and its associated faunal assemblage is of others of the same classification
Restoration	The process of returning the seabed to its former (un-impacted or pre-dredged) state and function
ROG	Recommended Operational Guidelines
Scuppers	Overflow spillways located in the top-sides of the hull of a dredger to allow displaced water from the hopper (hold) to return to the sea
Secondary Impact Zone (SIZ)	The area of seabed which is indirectly impacted by the action of dredging caused by the resuspension of nearbed sediments and the fall out of dredge plume sediment either as a result of overspill from the dredger hopper of from the screening chute. Secondary impacts by definition may occur both within and beyond the boundaries of the extraction licence. This is also equivalent to the indirect impact zone.
SOP	Standard Operating Procedure
Strata	A combination of seabed biotope and zones of dredging impact used to stratify benthic sampling
Substantive Review	The process of undertaking an assessment of the ecological conditions based upon a review of the monitoring data in relation to the baseline survey state at fixed periods during the lifetime of the licence as stated in the dredging permit Schedule of Conditions. This allows validation of magnitude of impacts as predicted by the EIA and conditional further surveys to assess the spatial extent of observed changes. It also allows the effectiveness of licence conditions to be assessed and modified accordingly.
Systematic	Arranged according to a system, method, or plan; regular; orderly

APPENDIX 2
References

Allen, P.L. and Rees, E.I.S., 1999. Irish Sea Seabed Image Archive (ISSIA): a directory of seabed camera studies in the Irish Sea. Report for the UK Department of Environment Transport and the Regions by School of Ocean Sciences, University of Wales Bangor. 82 pp + CD-ROM.

Bale, A.J. and Kenny, A.J. (2005). Sediment analysis and seabed characterisation. In: Eleftheriou, A. and McIntyre A.D. (eds.), 2005. Methods for the Study of Marine Benthos, 3rd edn, pp. 160-228. Blackwell, Oxford. 418 pp.

Barrio Froján, C.R.S. and Mason, C., 2010. A quantitative comparison between the sampling efficacy of the mini-Hamon grab and the Costerus twin grab (www.cefas.defra.gov.uk/alsf/projects/natural-seabed-resources/rec-0804/addendum-report.aspx).

Benedetti, L., 2001. Beyond BACI: Optimisation of environmental sampling designs through monitoring and simulation. Ecological Applications, 11(3): 783-799.

Bergstedt, R.A. and Anderson, D.R., 1990. Evaluation of line transect sampling based on remotely sensed data from underwater video. Transactions of the American Fisheries Society 119: 86-91.

Blott, S.J. and Pye, K., 2001. GRADISTAT: a grain size distribution and statistics package for the analysis of unconsolidated sediments. Earth Surface Processes and Landforms 26: 1237-1248.

BMAPA and English Heritage, 2003. Marine aggregate dredging and the historic environment: assessing, evaluating, mitigating and monitoring the archaeological effects of marine aggregate dredging. Guidance Note, British Marine Aggregate Producers Association and English Heritage, London.

Boyd, S.E. and Rees, H.L., 2003. An examination of the spatial scale of impact on the marine benthos arising from marine aggregate extraction in the central English Channel. Estuarine, Coastal and Shelf Science 57: 1-16.

British Standards Institution, 1996. BS1377 British Standards: Part 2: Methods of test for soils for civil engineering purposes: Classification tests. British Standards Institution, London, UK 61 pp.

Clarke, K.R. and Warwick, R.M., 1994. Change in marine communities: an approach to statistical analysis and interpretation. Plymouth Marine Laboratory, 1-144 pp.

Clarke, K.R. and Warwick, R.M., 1999. The taxonomic distinctness measure of biodiversity: weighting of step lengths between hierarchical levels. Marine Ecology Progress Series, 184: 21-29.

Clarke, K.R., Gorley, R.N., 2006. PRIMER v6: User Manual/Tutorial. PRIMER-E, Plymouth.

Coggan, R., Mitchell. A., White, J. and Golding, N., 2007. Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques. (www.searchmesh.net/PDF/GMHM3_Video_ROG.pdf).

Coggan, R., Populus, J., White, J., Sheehan, K., Fitzpatrick, F. and Piel, S. (eds), 2007. Review of Standards and Protocols for Seabed Habitat Mapping. MESH project document.

Connor, D.W., Allen, J.H., Golding, N., Howel, K.L., Lieberknecht, L.M., Northen, K.O. and Reker, J.B., 2004. The national marine habitat classification for Britain and Ireland. Version 04.05. Joint Nature Conservation Committee, Peterborough.

Cooper, K.M. and Rees, H.L., 2002. Review of Standard Operating Procedures (SOPs). Science Series, Aquatic Environment Protection: Analytical Methods, Cefas, Lowestoft No.13., 57 pp.

Curtis, M.A. and Coggan, R.A. 2006. Recommended operating guidelines (ROG) for MESH; trawls and dredges. (www.searchmesh.net/PDF/GMHM3_Trawls_and_Dredges_ROG.pdf).

Desprez, M., Pearce, B. and Le Bot. S., 2010. The biological impact of overflowing sands around a marine aggregate extraction site: Dieppe (eastern English Channel). ICES Journal of Marine Science, 67: 270-277.

DTLR, 2002. Guidelines for the conduct of benthic studies at aggregate dredging sites. Crown copyright, London 119pp (www.cefas.co.uk/publications/files/02dpl001.pdf).

Dyer, K.R., 1986. *Coastal and Estuarine Sediment Dynamics.* Wiley, Chichester, UK, 342 pp.

Eleftheriou, A. and Basford, D.J., 1989. The macrobenthic infauna of the offshore northern North Sea. J. Mar. Biol. Ass. U.K., 69: 123-143.

Eleftheriou, A. and McIntyre, A.D. (eds), 2005. Methods for the Study of Marine Benthos, 3rd edn. Blackwell, Oxford. 418 pp.

Eleftheriou, A. and Moore, D.C., 2005. Macrofauna techniques. In: Eleftheriou, A. and McIntyre A.D. (eds.), 2005. Methods for the Study of Marine Benthos, 3rd edn, pp. 160-228. Blackwell, Oxford. 418 pp.

Emery, W.J. and Thomson, R.E., 1997. Data analysis methods in physical oceanography. Pergamon, 634pp. European Communities. 1999. Commission Directive 1999/11/EC of 8 March 1999 adapting to technical progress the principles of good laboratory practice as specified in Council Directive 87/18/EEC on the harmonisation of laws, regulations and administrative provisions relating to the application of the principles of good laboratory practice and the verification of their applications for tests on chemical substances. Official Journal of the European Communities, L77: 8-21.

Folk, R. L., 1974. *Petrology of sedimentary rocks.* Hemphill, Texas, USA, 182 pp.

Gray, J.S., McIntyre, A.D. and Štirn, J., 1992. Manual of methods in aquatic environment research. Part 11 – Biological assessment of marine pollution - with particular reference to benthos. FAO Fisheries Technical Paper 324, Rome, 49 pp.

Hill, M.O., 1979. TWINSPAN/DECORANA: Fortran programs for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes and for ordinating multivariate species data (www.ceh.ac.uk/products/software/CEHSoftware-DECORANATWINSPAN.htm).

Hiscock, K. (ed.), 1996. Marine Nature Conservation Review: rationale and methods. Coasts and seas of the United Kingdom. MNCR series. Joint Nature Conservation Committee. Peterborough.

Holme, N.A. and McIntyre, A.D., 1984. Methods for the Study of Marine Benthos. IBP Handbook No.16 (2nd Edition). Blackwell, Oxford, 387 pp.

ICES, 2000. Working Group on Marine Data Management, Data Type Guidelines, (www.ices.dk/committe/occ/mdm/).

Jennings, S., Lancaster, J. Woolmer, A. and Cotter, J., 1999. Distribution, diversity, and abundance of epibenthic fauna in the North Sea. J. Marine. Biological Association U.K., 79: 385-399.

JNCC, 2001. The Marine Monitoring Handbook. Joint Nature Conservation Committee, Peterborough, 405 pp.

JNCC (2009). The identification of the main characteristics of stony reef habitats under the Habitats Directive. Summary report of an inter-agency workshop 26-27 March 2008. Final Report (v3), 2 March 2009.

Jongman, R.H.G., ter Braak, C.J.F. and van Tongeren, O.F.R., 1987. Data analysis in community and landscape ecology. Cambridge University Press, Cambridge, 299 pp.

Kelaher, B.P.*, Chapman, M.G. and Underwood, A.J. 1998. Changes in benthic assemblages near boardwalks in temperate urban mangrove forests. Journal of Experimental Marine Biology and Ecology, 228: 291–307.

Kenny, A.J. and Rees, H.L., 1994. The effects of marine gravel extraction on the macrobenthos: early post-dredging recolonisation. Marine Pollution Bulletin 28(7): 442-447.

Kenny, A.J. and Rees, H.L., 1996. The effects of marine gravel extraction on the macrobenthos: Results two years post-dredging. Marine Pollution Bulletin 32 (8/9): 615-622.

Kenny, A. J., Cato, I., Desprez, M., Fader, G., Schuttenhelm, R. T. E., and Side, J., 2003. An overview of seabed-mapping technologies in the context of marine habitat classification. ICES Journal of Marine Science, 60: 411–418.

Kimmel, J., 1985. A new species-time method for visual assessment of fishes and its comparison with established methods. Environmental Biology of Fishes. 12, 23-32.

Lambshead, P.J.D., Platt, H.M. and Shaw, K.M., 1983. The detection of differences among assemblages of marine benthic species based on an assessment of dominance and diversity. Journal of Natural History, 17: 859-874.

Limpenny, D.S., Foster-Smith, R.L., Edwards, T.M., Hendrick, V.J., Diesing, M., Eggleton, J.D., Meadows, W.J., Crutchfield, Z., Pfiefer, S. and Reach, I.S., 2010. Best methods for identifying and evaluating *Sabellaria spinulosa* and cobble reef. Aggregate Levy Sustainability Fund Project MAL0008. Joint Nature Conservation Committee, Peterborough, 134 pp.

Lincoln, R.J. and Sheals, J.G., 1979. Invertebrate animals. Collection and Preservation. British Museum (Natural History), 150 pp.

Malatesta, R.J., Auster, P.J., Carlin, B.P., 1992. Analysis of transect data for microhabitat correlations and faunal patchiness. Marine Ecology Progress Series, 87: 189-195.

Marine Ecological Surveys Limited. 2008. Marine Macrofauna Genus Trait Handbook. Marine Ecological Surveys Limited, 24a Monmouth Place, Bath, BA1 2AY. 184 pp.

Mason, C. in prep. NMBAQC Particle size analysis of sediment in support of biology, www.nmbaqcs.org.

MESH, 2006. MESH Habitats Signatures database. (www.searchmesh.net).

Michalopoulos, C., Auster, P.J. and Malatesta, R.J., 1992. A comparison of transect and species time counts for assessing faunal abundance from video surveys. Marine Technology Society Journal 26(4): 27-31.

Newell, R.C., Seiderer, L.J., Simpson, N.M. and Robinson, J.E., 2002. Impact of marine aggregate dredging and overboard screening on benthic biological resources in the central North Sea: Production Licence Area 408. Coal Pit. Marine Ecological Surveys Limited. Technical Report No. ER1/4/02 to the British Marine Aggregate Producers Association (BMAPA). 72 pp.

Newell, R.C., Seiderer, L.J., Simpson, N.M., Robinson, J.E., 2004. Impacts of marine aggregate dredging on benthic macrofauna off the south coast of the United Kingdom. Journal of Coastal Research 20, 115–125.

Oele, E., 1978. Sand and gravel from shallow seas. Geologie en Mijnbouw, 57: 45-54.

Proudfoot, R.K., Elliot, M., Dyer, M.F., Barnett, B.E., Allen, J.H., Proctor, N.L., Cutts, N.D., Nikitik, C., Turner, G., Breen, J., Hemmingway, K.L. and Mackie, T., 2000. Proceedings of the Humber benthic field methods workshop, Hull University 1997. Collection and processing of macrobenthic samples from soft sediments; a best practice review, 47 pp.

Rees, H.L. (ed.), 2004. Biological monitoring: general guidelines for quality assurance. ICES Techniques in Marine Environmental Sciences No. 32. 44pp.

Rees, H.L. (ed.), 2009. Guidelines for the study of the epibenthos of subtidal environments. ICES Techniques in Marine Environmental Sciences, No.42. 88pp.

Ricciardi, A. and Bourget, E., 1998. Weight-to-weight conversion factors for marine benthic invertebrates. Marine Ecology Progress Series, 163: 245-251.

Rumohr, H., Brey, T., and Ankar, S., 1987. A compilation of biometric conversion factors for benthic invertebrates of the Baltic Sea. Baltic Marine Biology, 9: 1-56.

Schratzberger, M., 1998. Effects of disturbances on nematode assemblages. PhD thesis, University of Hamburg, Germany, 226pp.

Service, M. and Golding, N., 2001. Procedural Guideline No. 3-14 In situ survey of sublittoral epibiota using towed sledge video and still photography. In: Davies, J., Baxter, J., Bradley, M., Connor, D., Khan, J., Murray, E., Sanderson, W., Turnbull, C. and Vincent, M. Marine Monitoring Handbook. Joint Nature Conservation Committee, Peterbrough.

Skilleter G.A., Pryor, A., Miller, S. and Cameron, B., 2006. Detecting the effects of physical disturbance on benthic assemblages in a subtropical estuary: A Beyond BACI approach. Journal of Experimental Marine Biology and Ecology, 338: 271-287.

Underwood, A.J., 1991. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Australian Journal of Marine and Freshwater Research, 42: 569-587.

Underwood, A.J., 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. Journal of Experimental marine Biology and Ecology, 161: 145-178.

Underwood, A.J., 1993. The mechanics of spatially replicated sampling programmes to detect environmental impacts in a variable world. Australian Journal of Ecology, 18: 99-116.

Underwood, A.J., 1994. On beyond BACI: sampling designs that might reliably detect environmental disturbances. Ecological Applications, 4(1): 3-15.

Underwood, A.J., 1996. Detection, interpretation, prediction and management of environmental disturbances: some roles for experimental marine ecology.

Underwood, A.J., 1997. Experiments in ecology: their logical design and interpretation using analysis of variance. Cambridge University Press, Cambridge.

Underwood, A.J., Chapman, M.G. and Connell, S.D., 2000. Observation in ecology: you can't make progress on processes without understanding the patterns. Journal of Experimental Marine Biology and Ecology, 250: 97-115.

Underwood, A.J. and Chapman, M.G., 2003. Power, precaution, Type II error and sampling design in assessment of environmental impacts. Journal of Experimental Marine Biology and Ecology, 296: 49-70.

UNESCO, 1988. The acquisition, calibration and analysis of CTD data. UNESCO technical papers in marine science, SCOR WG 51.

UNESCO, 1993. Manual of quality control procedures for validation of oceanographic data. Prepared by CEC:DG- XII, MAST and IOC. IOC-CEC Manual + Guides 26, 436pp.

Warwick, R.M., 1986. A new method for detecting pollution effects on marine macrobenthic communities. Marine Biology, 92: 557-562.

Water Authorities Association, 1988. Mixing zones: the control of industrial discharges to surface waters. London: Water Authorities Association, 12pp.

Wentworth, C.K., 1922. A scale of grade and class terms for clastic sediments. Journal of Geology, 30: 377-392.

APPENDIX 3
Sources of Useful Information & Data

Regulatory documents

- Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (England and Northern Ireland) Regulations 2007: www.opsi.gov.uk/si/si2007/uksi_20071067_en_1
- Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (Scotland) Regulations 2007: www.oqps.gov.uk/legislation/ssi/ssi2007/ssi_20070485_en_1
- Environmental Impact Assessment and Natural Habitats (Extraction of Minerals by Marine Dredging) (Wales) Regulations 2007: www.opsi.gov.uk/legislation/wales/wsi2007/wsi_20072610_en_1
- Habitats directive: Council Directive 92/43/EEC on the Conservation of natural habitats and of wild fauna and flora
- JNCC guidelines for minimising the risk of disturbance and injury to marine mammals from seismic surveys (August 2010): www.jncc.gov.uk/PDF/Seismic%20Guidelines%20June%202009_ver01.pdf
- Marine Minerals Guidance Note 1: Extraction by Dredging from the English Seabed: www.communities.gov.uk/documents/planningandbuilding/pdf/156357.pdf
- Marine Minerals Guidance Note 2: The Control of Marine Minerals Dredging from the British Seabed: www.marinemanagement.org.uk/works/minerals/mmg2.htm

Useful websites

- Biological Traits Information Catalogue (Biotic): www.marlin.ac.uk/biotic
- British Geological Survey (BGS): www.bgs.ac.uk
- British Oceanographic Data Centre (BODC): www.bodc.ac.uk
- Data Archive for Seabed Species and Habitats (DASSH): www.dassh.ac.uk
- MarBEF: www.marbef.org
- Mapping European Seabed Habitats (MESH): www.searchmesh.net
- Marine Environment Protection Fund (MEPF-MALSF)): www.cefas.defra.gov.uk/alsf
- Marine GIS for MALSF Data & Reports (and other Marine Aggregate-related Data; www.marinealsf.org.uk
- Marine Management Organisation (MMO): www.marinemanagement.org.uk
- MEDIN: www.oceannet.org
- Multivariate statistical analysis: www.primer-e.com
- National Biodiversity Network: www.nbn.org.uk
- National Marine Biological Analytical Quality Control Scheme (NMBAQC): www.nmbaqcs.org
- Navigator for MALSF Projects: www.marinealsf-navigator.org.uk
- On-line Genus Traits Handbook: www.genustraithandbook.org.uk
- SeaZone: www.seazone.com
- The Crown Estate: www.thecrownestate.co.uk
- United Kingdom Hydrographic Office (UKHO): www.ukho.gov.uk

APPENDIX 4

Cefas Environmental Assessment Reference Stations (EARS)

Table 6. Cefas Environmental Assessment Reference Stations (EARS)

EARS Site	*Code*	*Latitude (WGS84)*	*Longitude (WGS84)*
Isle of Wight	G03	050° 42.840' N	000° 53.006' W
Isle of Wight	G10	050° 39.851' N	000° 52.999' W
Isle of Wight	G12	050° 39.885' N	000° 43.863' W
Isle of Wight	G21	050° 37.534' N	000° 52.896' W
Isle of Wight	G22	050° 37.525' N	000° 48.585' W
Isle of Wight	G37	050° 34.636' N	000° 53.098' W
Isle of Wight	G53	050° 26.791' N	000° 53.047' W
Isle of Wight	G55	050° 26.894' N	000° 36.129' W
Cross Sands	G16	052° 38.138' N	002° 02.705' E
Cross Sands	G23	052° 32.494' N	002° 02.671' E
Cross Sands	G24	052° 32.354' N	002° 08.592' E
Cross Sands	G26	052° 31.356' N	002° 00.447' E
Cross Sands	G3	052° 48.649' N	002° 06.864' E
Cross Sands	G30	052° 29.942' N	002° 02.558' E
Cross Sands	G34	052° 26.590' N	002° 00.548' E
Cross Sands	G38	052° 21.787' N	002° 02.656' E
Eastern English Channel	HG1	050° 39.300' N	000° 56.280' E
Eastern English Channel	HG10	050° 20.760' N	000° 08.880' E
Eastern English Channel	HG2	050° 34.380' N	000° 41.340' E
Eastern English Channel	HG3	050° 30.720' N	000° 30.420' E
Eastern English Channel	HG4	050° 29.525' N	000° 26.522' E
Eastern English Channel	HG5	050° 29.220' N	000° 24.060' E
Eastern English Channel	HG6	050° 30.780' N	000° 24.600' E
Eastern English Channel	HG7	050° 28.200' N	000° 25.920' E
Eastern English Channel	HG8	050° 27.840' N	000° 20.520' E
Eastern English Channel	HG9	050° 24.780' N	000° 08.220' E

APPENDIX 5

General Guidance on Standard Operating Procedures (SOPs)

A well-written SOP will help new or inexperienced members of staff in a laboratory to develop expertise in a sampling or analytical procedure that is not only consistent with past practice at that laboratory, but also compatible with established approaches elsewhere. For those seeking laboratory accreditation, the production of SOPs is an essential part of a wider QA programme, but even for others, they provide an important means of fostering good internal practice. However, SOPs in themselves are clearly not guarantors of data quality.

SOPs should describe all steps performed in biological measurement. They should be established to cover the following areas of activity:

- Station selection and location, navigational accuracy.
- Handling, maintenance, and calibration of field and laboratory equipment.
- Handling and use of chemicals (i.e. fixatives, preservatives, reagents) used in marine environmental surveys.
- Collection of biological material.
- Storage of biological material, including labelling and the checking of preservation status.
- Distribution of biological material to external contractors/taxonomic specialists.
- Analytical methods for biological material.
- Identification of biological material, including taxonomic expertise of the personnel.
- Recording of biological and environmental data; data management.
- Analysis of biological and environmental data.
- QA of report writing and documentation, including signed protocols in all steps of analysis.

In considering best practice, it is recommended that SOPs should:

- Be structured logically by heading and sub-heading to cover the full sequence of activities in field sampling and laboratory analysis.
- Carry an issue number, date and name(s) of the individual(s) responsible for its drafting and updating. This anticipates a likely requirement for changes to SOPs in response to new equipment, guidelines, etc.
- Document in-house AQC procedures.
- Account for the specific practices of the individual laboratory. At the same time, SOPs must reflect agreed guidelines applicable at national or international level; for example, relating to nomenclature and coding systems employed in documenting the outcome of the analysis of field-collected specimens.
- Contain a full listing of taxonomic keys used for laboratory identification, and other useful reference works relating to procedures.
- Be filed as paper copies in an accessible place, as well as being available on a computer network.
- Be freely available to all interested parties (especially funding agencies).

- Contain explicit instructions for the tracking of samples from the point of collection to the point of archiving of analysed material.

SOPs may usefully contain:

- Diagrams depicting gear, especially where local modifications to equipment are made.
- A summary flow-chart as an accompaniment to a lengthy SOP, as an *aide-mémoire* for field and laboratory bench operators.
- Details of local suppliers, manufacturers, etc., where relevant.

SOPs should not:

- Contain vague generalisations.
- Contain excessive detail; a sensible balance must be achieved which takes into account the basic level of training and common sense that a new operator will possess.
- Cover too many activities; for example, it is logical to have separate SOPs for field and laboratory procedures. Different types of field activity such as intertidal core sampling and shipboard sampling are also sensibly treated separately.

The preparation of SOPs to cover field and laboratory analytical activities is one of the most important practical steps that a laboratory/institute can take in seeking to improve the quality and consistency of its scientific products and is, therefore, to be strongly recommended. This having been done, inter-laboratory comparisons of SOPs may then provide a useful tool in identifying any remaining inconsistencies, and hence in promoting harmonisation of methodology at a national and international level (see, for example, Cooper and Rees, 2002). Such periodic comparisons of SOPs are also to be strongly recommended.

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