Cyfoeth Naturiol Cymru
Natural Resources Wales

Guidance Note

Benthic habitat assessment guidance

Over-arching principles and methods for benthic marine habitat survey and monitoring in the context of ecological impact assessment

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What is this document about?

This introductory technical chapter provides guidance on over-arching principles and methods for benthic marine habitat survey and monitoring in the context of Ecological Impact Assessment (EcIA) as part of the regulatory development control process.

Who is this document for?

This is best practice technical guidance for developers designing marine benthic habitat surveys and monitoring in relation to maritime developments.

Contact for queries and feedback

marine.area.advice@cyfoethnaturiolcymru.gov.uk

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To report issues or problems with this guidance contact Guidance Development

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1.Introduction

This guidance has been prepared by Natural Resources Wales (NRW) with the initial introductory chapter prepared under contract by APEM Ltd and Ocean Ecology Limited. This introductory technical chapter provides guidance on over-arching principles and methods for benthic marine habitat survey and monitoring in the context of Ecological Impact Assessment (EcIA) as part of the regulatory development control process.

The guidance presents methods and approaches that are considered by NRW Advisory to constitute best practice. We want you to consider them if you are preparing and carrying out benthic marine habitat surveys to inform an ecological impact assessment and for any monitoring that may be required pre-, during or post development as part of the regulatory control process.

The guidance is not overly prescriptive since the methods and approaches for survey and monitoring will need to be tailored to the specific nature and scale of the proposed development or activity and any associated requirements for ecological assessment.

This introductory chapter (GN030-intro) is accompanied by an over-arching Guidance Note (GN030) and a series of chapters (GN030a-h) that deal with specific benthic marine habitats of conservation importance in Wales. The individual habitat chapters provide technical information on more habitat-specific methods that build on the over-arching principles provided in this introductory chapter.

The habitat chapters (GN030a-h) are not intended to be used alone and should always be used in conjunction with this Introductory chapter (GN030-intro) and the Guidance Note GN030

This introductory chapter also provides advice on the sort of detail that NRW Advisory would expect to see when presented with either proposals for, or reports on benthic habitat characterisation surveys and monitoring as part of either pre-application advice (if sought) or, the formal regulatory control assessment process. Providing the required information at the appropriate level of detail will assist your application.

2. Benthic marine habitat characterisation surveys and monitoring – what information do you need to provide?

The type and amount of survey and monitoring that you need to undertake will depend on the nature, scale and location of your proposed development or activity. You will need to consider what is required and design your survey and monitoring accordingly.

When NRW Advisory is consulted in relation to applications for proposed developments and activities, the sort of information and level of detail that we expect you to provide in terms of benthic habitat survey and monitoring is outlined below. These requirements are considered further in sections 3 and 4 and in the individual habitat chapters of this guidance. The Guidance Note GN030 explains where you can find out more information about NRW's advisory role, the types of advice we provide for free and those that will be charged for.

Whether we are consulted as part of a pre-application enquiry or during formal consultation by the regulator, we need to be able to understand the rationale behind your survey and monitoring and why you have proposed your stated approach and scope of work. We also need to see specific detail relating to the proposed methods and approaches. Having this level of detail helps us assess the appropriateness of the proposed survey and monitoring work and helps streamline the consultation process.

2.1. Benthic marine habitat characterisation surveys

If you are submitting proposals for benthic marine habitat characterisation surveys, the sort of information that NRW Advisory would expect to receive is set out below. This is not a definitive list but provides a series of prompt questions to help you understand the information and level of detail that we are looking for.

1. The Zone of Influence for your development (section 3.1 below)
- Have you defined the Zone of Influence?
- Have you considered all aspects of the proposed works and the implications of these for the likely area that will be affected?
- Have you considered any likely far-field affects that may arise from your development during both construction and operation? For example, the influence of your proposal on coastal processes and the implications of this for potential impacts on benthic habitats?
- If appropriate, have you identified primary and secondary impact zones? (Section 4.2.4 below).
- Are there current areas of uncertainty about potential affects and the Zone of Influence that may subsequently require further work?

2. Use of existing data (section 3.2.3 below)
- Have you looked at and used existing data to design your survey?
- If you have used existing data, what data have you used and how have you used it?

3. Habitats of conservation importance (section 3.2.2 below)

- If there are, or there is potential for them to be present, how have you taken these into account in planning your survey and the methods to be used?

4. Habitat sensitivity and pressures likely to arise from the proposed development / activity (section 3.2.6 below)

- Have you identified the pressures that are likely to arise from your proposed development or activity and related these to the sensitivity of habitats known or likely to be present in the Zone of Influence or survey area?
- How have you taken the sensitivity of habitats into account in your survey approach?

5. Ecological parameters for the survey (section 3.2.7 below)

- Have you identified the ecological parameters that you want to survey for?
- Have you explained why you have chosen these ecological parameters and how they relate to the likely potential effects of the proposed development or activity?
- Are the ecological parameters appropriate to provide a baseline if you need to undertake any benthic habitat monitoring?

6. Survey methods – general

- Have you clearly explained the survey method(s) you intend to use for the expected seabed type(s)?
- Have you explained why you have chosen the methods?
- Have you used NRW's guidance for the chosen survey method(s)?
- Will you be complying with recommended guidelines and quality control procedures (for example, NMBAQC for video survey and grab analysis)? Have you provided details of your quality control procedures?
- Have you identified how you intend to analyse the survey data? Are the chosen survey methods compatible with the intended analysis so they provide, for example, statistical robustness?

7. Survey methods – geophysical survey

- Are you going to undertake a geophysical survey?
  This will generally be required for large developments where the seabed type is unknown or low confidence. In some circumstances, smaller developments may also require a geophysical survey, especially if the extent of habitats like Annex I Reef need to be determined.
- Has the geophysical survey been done using the appropriate techniques and does it cover all the areas to be affected?
- Have you used NRW's guidance for carrying out and analysing geophysical survey?

8. Survey sites

- How many survey sites have you chosen?
- Have you explained why you have chosen the stated number of sites and why this is sufficient for the expected seabed type(s)?
- What are the exact positions of your proposed survey sites?

- Have you provided a map that shows your proposed survey sites in context of the development and Zone of Influence?

9. Sample replicates (section 3.2.10 below)
- Does your survey sampling require replicate samples?
- Have you explained why you have chosen the approach you intend to use?

2.2. Benthic marine habitat monitoring

If you are submitting proposals for monitoring benthic marine habitats in the context of EcIA, the sort of information that NRW Advisory would expect to receive is set out in Table 2. This is not a definitive list but provides a series of prompt questions to help you understand the sort of information and level of detail that we are looking for.

1. The purpose of the monitoring programme
- Why are you monitoring?
- Have you clearly explained the purpose of the monitoring programme?

2. The Zone of Influence for your development (section 3.1 below)
- Have you defined the Zone of Influence?
- Have you considered all aspects of the proposed works and the implications of these for the likely area that will be affected?
- Have you considered any likely far-field affects that may arise from your development during both construction and operation? For example, the influence of your proposal on coastal processes and the implications of this for potential impacts on benthic habitats?
- If appropriate, have you identified primary and secondary impact zones? (Section 4.2.4 below).
- Are there current areas of uncertainty about potential affects and the Zone of Influence that may subsequently require further work?

3. Use of existing data (sections 3.2.3 and 4.2 below)
- Have you looked at and used existing survey or monitoring data within your monitoring programme?
- If you have, what data have you used and how have you used it?

4. Habitats of conservation importance (section 3.2.2 below)
- Are any of the habitats where the monitoring is taking place known to be habitats of conservation importance?
- If there are, or there is potential for them to be present, how have you taken these into account in planning your monitoring and the method(s) to be used?

5. Habitat sensitivity and pressures likely to arise from the proposed development or activity (section 3.2.6 below)

- Have you identified the pressures that are likely to arise from your proposed development or activity and related these to the sensitivity of habitats known, or likely to be present in the area where you are monitoring?
- How have you taken the sensitivity of habitats into account in your monitoring methods and approach(es)?

6. Indicators (section 4.2.1 below)
- Have you identified the ecological parameters that you want to act as indicators for your monitoring programme?
- Have you explained why you have chosen these indicators and how they relate to the likely potential effects of the proposed development or activity?
- Do you have sufficient data for these indicators to provide an adequate pre-development baseline? Have you explained this in your monitoring approach?

7. Hypotheses and trigger levels (sections 4.2.2 and 4.2.3 below)
- Have you clearly identified the hypotheses for your monitoring programme?
- Have you explained what statistical analysis you will undertake to test your hypotheses?
- Have you identified trigger levels for specific indicators within your monitoring programme?
- Are the trigger levels appropriate and measurable? Have you explained why?
- Have you explained how the hypotheses and trigger levels relate to the pressures and likely effects of the proposed works and the EcIA?
- Are there management measures identified in the event that trigger levels are exceeded?

8. Monitoring programme design and methods (section 4.2.5 below)
- Have you clearly explained the design of your monitoring programme and the approach(es) you have chosen?
- Have you included information about:
  - the number and location of sample sites and why this is sufficient for the habitats and predicted likely affects?
  - the number and location of control sites outside of the Zone of Influence and reasons for their selection?
  - the duration and frequency of monitoring?
- Have you explained how the monitoring design relates to the Zone of Influence, likely pressures and affects arising from the proposed development or activity and the EcIA?
- Have you clearly explained the method(s) you intend to use for the monitoring? Have you explained why you have chosen these?
- Have you used NRW's guidance for the chosen monitoring approach(es) and method(s)?
- Will you be complying with recommended guidelines and quality control procedures (for example, NMBAQC for video survey and grab analysis)? Have you provided details of your quality control procedures?
- Have you identified how you intend to analyse the monitoring data? Are the chosen survey methods compatible with the intended analysis (e.g. for statistical robustness)?

9. Sampling effort, power analysis and replicates (sections 4.2.4 and 4.2.5.3 below)

- Have you explained what the sampling effort is for your monitoring programme? Have you explained how you determined the intended level of sampling effort?
- Have you undertaken power analysis for your proposed sampling and explained this within your programme design? What have you taken into account when conducting the power analysis?
- What are the exact positions of your proposed sample sites, including control sites?
- Have you provided a map that shows your proposed sample and control sites in the context of the proposed development and Zone of Influence?
- Does your sampling require replicate samples? Have you explained your rationale for the number of replicate samples?
- Have you explained why you have chosen the approach you intend to use and how this relates to subsequent analysis of the monitoring data?

3. Benthic marine habitat characterisation

Summary

When there is insufficient information to enable a robust Ecological Impact Assessment to be undertaken for a proposed development or activity, you may need to undertake benthic marine habitat characterisation surveys to contribute to the overall site characterisation required for the assessment.

The design of the survey(s) will differ on a case-by-case basis and should be informed by available existing ecological information and the nature of the proposed development or activity. Your survey(s) should be conducted in line with existing best practice guidance and enable you to:

- Define the Zone of Influence of your proposed activity.
- Describe the benthic habitats present within the Zone of Influence
- Select ecological parameters to assess key marine receptors and determine whether these parameters could be used as indicators for subsequent monitoring if that is required
- Decide whether your habitat characterisation will also form part of your baseline for subsequent monitoring and, if so, whether it needs to include control stations and within-station replication

3.1. Aims of benthic marine habitat characterisation surveys

The aim of site characterisation is to provide up-to-date ecological data to inform an Ecological Impact Assessment (EcIA), for example, as part of an Environmental Impact Assessment (EIA), Habitats Regulation Assessment (HRA), Strategic Environmental Assessment (SEA), Water Framework Directive (WFD) assessment or Marine Conservation Zone (MCZ) assessment. Where benthic marine habitat data is required as part of site characterisation, the main information required in relation to the habitats is:

- The distribution of different habitats across the potential Zone of Influence (ZoI, the area of the seabed or foreshore that could be affected by the proposed development or activity, during both construction and/or operation.) of a proposed development or activity. This may be as a habitat or biotope map, if applicable
- The characterisation of biotic communities across the ZoI, preferentially encompassing communities in each of the main habitats or sub-habitats present. This could include identifying the different taxa within assemblages, along with their densities, and the subsequent calculation of summary statistics such as diversity indices
- The presence or absence of any habitats or species of conservation importance, or non-native species
- An indication of variation in the above parameters across spatial scales.
- An indication of variation in the above parameters across temporal scales, where possible (though this may not be required and will depend on the nature and scale of the proposed development or activity).

Ideally the survey will be supported by historic data, as this can help to identify knowledge gaps and provide specific information for designing any further surveys that are required. Existing data may be sufficient for the purposes of the EcIA but, where it isn't, you may need to collect additional information.

3.2. Designing benthic marine habitat characterisation surveys

3.2.1. The proposed development or activity

Information about your proposed development or activity, for example construction methods or operational information, plays a key role in informing an effective survey design, in particular:

- Any plans that indicate the location, spatial and temporal extent of the ZoI
- Detail that indicates the potential for near-field and far-field effects beyond the footprint of any structures, including any supporting modelling. For example, if large-scale dredging is required for your development, sediment transport modelling outputs may be available to inform the benthic habitat survey design
- Once the ZoI is identified, a targeted benthic habitat characterisation survey can be designed. The scope and design of the survey needs to take account of the nature of your proposed development or activity and potential impacts on benthic marine habitats and species

Large-scale developments or activities, for example tidal lagoons, with a capacity for far-field effects on marine habitats and associated species assemblages, will have extensive benthic habitat characterisation requirements. These may encompass elements of remote sensing (e.g. collection of geophysical data) as well as direct physical sampling.

For **small-scale developments or activities**, for example the construction of a small jetty structure, targeted field-based surveys might be sufficient to provide the data required for EcIA.

3.2.2. Marine benthic habitats of conservation importance

You should refer to relevant legislation and policy to help you identify the conservation value of the habitats and species in the ZoI for your proposed development or activity. NRW advise that you do this early on in the EcIA process, as this can have a significant bearing on both the ecological assessment and habitat survey requirements.

Table 3 sets out some of the key legislation and policies in Wales relevant to benthic marine habitats of conservation importance and the relevance of these to benthic habitat surveys and monitoring in the context of EcIA. Other legislation and policy are also likely to be relevant depending on factors such as the location of the proposed development or activity. Additional habitat-specific information on legislation is provided in the accompanying habitat chapters GN030a-GN030h.

International

Habitats Directive Council Directive 92/43/EEC)

- The Habitats Directive lists habitats and species of interest in Annex I and Annex II respectively. Special Areas of Conservation (SACs) are protected sites which are designated based on the presence of habitats or species in these annexes.
- You will need to identify whether there is an impact pathway from your proposed development or activity through which your proposal may affect any SACs.
- All new or planned activities that may affect a SAC must be assessed to ascertain whether they would compromise the features of the site.
- You may have to provide benthic habitat data for the site features to the regulator, so they can undertake this assessment. You may be required to monitor potential impacts on protected SAC features.

Birds Directive (Directive 2009/147/EC)

- This European directive aims to protect all European wild birds. The habitats and suitable territories of listed species are further protected through the designation of Special Protection Areas (SPAs).
- You will need to identify whether there is an impact pathway from your proposed development or activity through which your proposal may affect any SPAs.
- All new or planned activities that may affect a SPA must be assessed to ascertain whether they would compromise the features of the site.
- You may have to provide benthic habitat data to the regulator for habitats important for the bird species protected by a SPA, so they can undertake this assessment. You may be required to monitor potential impacts on SPA features which could include monitoring the benthic habitats used by them.

Ramsar Convention on Wetlands of International Importance

- Under the Ramsar Convention the UK is committed to conserving and sustainably using wetlands (which include marine habitats such as intertidal mudflats).
- UK and Welsh Government policy requires Ramsar sites to be treated as European sites and given the same level of protection as SACs and SPAs. The regulator will need to assess the implication of any proposed development or proposal on Ramsar sites and their protected features.
- You may need to provide information to the regulator for any development or activity that you want to undertake to enable them to undertake this assessment.

Water Framework Directive (WFD) (EU Directive 2000/60/EC)

- The Water Framework Directive requires that all inland and coastal ground and surface waterbodies within defined river basin districts (including marine waters up to one nautical mile from shore) are assessed and allocated an ecological status (or ecological potential if considering a Heavily Modified Water Body) on the scale of High, Good, Moderate, Poor and Bad.

- Under the WFD all inland and coastal waters must reach at least Good status or potential within a set timeframe, to be achieved by establishing environmental objectives and ecological targets for surface waters.
- Activities with the potential to impact any waterbody will require the regulator to conduct a WFD assessment to determine whether a development or activity will cause or contribute to deterioration of waterbody status or jeopardise the waterbody achieving good status.
- You may need to collect benthic habitat data to complete a WFD assessment.

Marine Strategy Framework Directive (MSFD) (Directive 2008/56/EC)

- The MSFD outlines a legislative framework for an ecosystem-based approach to the management of human activities which supports the sustainable use of marine goods and services.
- The overarching goal is to achieve 'Good Environmental Status' (GES) by 2020 across Europe's marine environment; note that this is not associated in any way with the 'ecological status/potential' assigned under the WFD.
- Defra (2014) outlines broad monitoring objectives and Defra (2015) outlines the UK's programme of measures that will help to achieve or maintain GES.
- Achieving GES will, in part, be achieved by meeting the obligations set by other EU Directives such as the Habitats and Birds Directives.
- Regulators will need to consider the requirements of MSFD in any assessments they undertake through legislation and policy that contributes to MSFD.

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the OSPAR Convention 1992):

- OSPAR List of threatened and/or declining species and habitats
- OSPAR Marine Protected Areas
    - The OSPAR Convention established cooperation between European countries to protect the marine environment of the North-East Atlantic.
    - The OSPAR List of Threatened and/or Declining Species and Habitats identifies species and habitats that are considered to be priorities for protection.
    - You may need to identify whether your proposed development or activity is likely to affect any of these species or habitats and provide this information to the regulator.
    - In addition, OSPAR's biodiversity strategy is to establish a network of ecologically coherent and well-managed Marine Protected Areas (MPAs). Sites submitted by the UK to be OSPAR MPAs are existing designated sites that support relevant habitats and species (including, but not limited to those on the OSPAR list of threatened and/or declining species and habitats).
    - OSPAR MPAs are protected through the existing mechanisms for protected sites (SACs, SPAs, SSSI) so that any information you are required to submit in relation to these will also contribute to the UK's obligations for OSPAR MPAs.

National

Environment (Wales) Act 2016: Section 7 list of habitats and species of principal importance

- Section 7 of the Environment (Wales) Act lists species and habitats that are considered to be of key significance to sustain and improve biodiversity in Wales; (this supersedes the previous S42 lists of the Natural Environment & Rural Communities (NERC) Act 2006).
- Welsh Ministers must take all reasonable steps, and encourage others to take such steps, to maintain and enhance the species and habitats on this list. Also, public bodies must have regard to this list in complying with their duty (section 6 of the Act) to maintain and enhance biodiversity in the exercise of their functions.
- You may need to identify whether your proposed development or activity is likely to affect any of these species or habitats and provide this information to the regulator in order for them to be able to comply with their biodiversity duties under the Act.

The Wildlife and Countryside Act 1981 (amended by the Countryside and Rights of Way (CROW) Act 2000)

- The Act provides for the designation of Sites of Special Scientific Interest (SSSIs). SSSIs are designed to protect the full range of variation (biological and geographic) in semi-natural habitats including the best examples of each type.
- Potential impacts on SSSIs are an integral consideration in the regulatory development control process. If your development or activity has the potential to affect SSSI features, you may have to provide information to the regulator to help them assess the potential impacts.

Marine and Coastal Access Act

- The Act enables Marine Conservation Zones (MCZs) to be designated to conserve 'nationally important' features including marine flora, fauna, habitats, and geological or geomorphological structures. The only MCZ currently designated in Wales is the Skomer MCZ.
- The Act is also responsible for the requirement for marine licences for developments and activities in the marine environment. If your proposed development or activity requires a marine licence you will need to submit sufficient information to the regulator for your proposal to be assessed.

Welsh Marine Protected Area Network

- Wales is committed to developing an ecologically coherent well managed network of MPAs. The network in Wales is made up of SACs, SPAs, SSSIs, RAMSAR sites and (at present) a single MCZ. A summary of the importance of the Welsh Marine Protected Area Network is provided in JNCC (2016).

Draft Wales National Marine Plan (WNMP)

- The WNMP will set out the Welsh Minister's policies for sustainable development of Wales' seas. Once adopted, all authorisation and enforcement decisions relevant to the marine are will need to comply with the policies set out in the plan.
- Relevant examples of draft plan policies include policies relating to the protection and restoration of marine biodiversity, Marine Protected Areas, effects on coastal change and flooding, and the proportionate use of evidence to support decision-making.

3.2.3. Use of existing data to inform the benthic habitat survey design

Before designing any benthic habitat characterisation survey, you need to scope the requirements for the survey. As part of this it is best, if possible, to conduct a desk-based review of all available data relevant to the ZoI. Historic data will help you identify knowledge gaps and provide specific information to inform your benthic habitat survey design, such as the number and location of sample stations.

Our guidance Note (GN006 Marine ecology datasets for marine developments and activities (Natural Resources Wales, 2019)) provides information on the marine ecology data that we hold and routinely use and how you can access them. It also includes details of available benthic habitat mapping outputs held by ourselves and others and explains where you can view and download information about marine protected areas and protected habitats and species.

3.2.4. Benthic habitat classification

There are a number of different habitat classification systems that are in use for both marine and terrestrial biological communities. They enable ecological communities and habitat types of interest to be consistently recorded, as well as providing a common language through which data can be communicated at a national and international level.

The marine habitat classification systems are most relevant to this guidance but, in the case of saltmarsh habitat, terrestrial classification systems are also used.

Marine habitat classification

There are two marine habitat classifications systems that are commonly used in the UK and which define all the marine habitats known to occur in the UK:

- The Joint Nature Conservation Committee (JNCC) Marine Habitat Classification for Britain and Ireland:
  The JNCC developed a hierarchical classification for marine habitats or biotopes (seashore and seabed habitats and their associated communities of species) in Britain and Ireland, producing one of the most comprehensive marine classification systems currently in use. The original version covered the littoral zone to the deep-circalittoral zone (Version 04.05, Connor *et al*. 2004) and the latest version (ver. 15.03) adds a new deep-sea section (Parry *et al*. 2015).

- The European Nature Information System (EUNIS):
  EUNIS is a pan-European system developed by the European Environment Agency to provide a comprehensive habitat classification for Europe. The Marine Habitat Classification for Britain and Ireland has been incorporated into the EUNIS

classification and there are correlation tables between the two systems that can be downloaded from the JNCC website. Biotope classifications can change over time and we recommend the JNCC website as a reference point to determine the latest guidance documentation for habitat/biotope assignment.

The EUNIS classification code is now most commonly used for mapping habitats/biotopes in a GIS, although the JNCC Marine Habitat Classification Scheme (Connor *et al*. 2004 and Parry *et al.* 2015) may also be used. Where possible, the Lifeform colouration system for different habitats/biotopes should be used for mapping outputs as indicated in Wyn *et al*. (2006).

Terrestrial habitat classification

Whilst there is a marine biotope that can be allocated to saltmarsh habitat, the classification of saltmarsh vegetation communities is fully covered by the UK National Vegetation Classification (NVC). The NVC is a classification system for British plant communities (vascular plants, bryophyte and macro-lichen species). It recognises a range of different saltmarsh habitats and their associated communities of species. There are correspondences between the NVC and the EUNIS classification system and a spreadsheet of these can be downloaded via the JNCC website.

Phase 1 surveys and habitat classifications

Phase 1 habitat classification has been applied to both marine and terrestrial situations. In both cases, the approach was designed to provide standardised systems at a simplified level of classification compared with the JNCC Marine Habitat Classification, NVC and EUNIS, in order to survey large areas of land, coast and shore relatively rapidly to provide a basic assessment of habitat type.

Whilst a greater level of detail may be required in many situations, the marine Phase 1 classification can be applied to benthic habitat characterisation surveys and further detail on this is provided in the relevant habitat chapters of this guidance.

3.2.5. Use of mapped data

Mapped data can be very helpful to display and understand the spatial relevance of survey data. Biological and other point sampling data may be incorporated as specific spatial data sets detailing sampling locations, with further data incorporated into relevant attribute tables.

Displaying sampling data in a spatial mapping context helps you to corroborate geophysical and ground-truthing data, identify subtle spatial variations, and delineate the extents of features and habitats of interest. Bubble plots can be produced within a GIS to provide a highly visual output to indicate data such as ranges for the number of taxa, or number of individuals at each sample station, with larger bubbles representing higher numbers of taxa/individuals.

3.2.6. Sensitivity of benthic habitat(s)

In the context of benthic marine habitat characterisation surveys, the sensitivity of benthic habitats is a relevant consideration for survey scoping and design for the following reasons:

- The sensitivity of habitats within the ZoI may influence your survey design and selection of survey methodology in order to avoid adverse impact on the habitats as a result of the survey. This requires assessment of existing information for the ZoI and adjacent areas to inform initial decisions about the potential presence of habitats and species with moderate to high sensitivity to potential impacts arising from your survey
- Once seabed habitats have been characterised, their sensitivity to the pressures that are likely to arise from your proposed development or activity may indicate a need for further work to inform the EcIA

Sensitivity can be defined as: “the likelihood of change when a pressure is applied to a feature (receptor) and is a function of the ability of the feature to tolerate or resist change (resistance) and its ability to recover from impact (resilience)” (Tillin *et al*. 2010, Tillin & Tyler-Walters 2014).

The Marine Life Information Network (MarLIN) website provides sensitivity reviews for individual marine habitats together with information relating to definitions of resistance and resilience, including scales of measurement and timeframes. Relevant information from MarLIN sensitivity reviews has been provided in each of the individual habitat chapters of this guidance (GN030a-h).

It is important to understand that the MarLIN sensitivity assessment approach assesses habitat sensitivity against a set benchmark and therefore the scale of effect from your proposed development or activity needs to be considered in relation to this. For example, when assessing sensitivity to smothering and siltation rate changes, the MarLIN benchmark is “deposition of up to 5 cm (light) or 30 cm (heavy) of fine material added to the habitat in a single, discrete event”. Consequently, if a proposed activity could result in deposition of sediment greatly in excess of this, a habitat assessed as having low sensitivity to smothering may actually have a higher sensitivity to this pressure due to the proposed activity. This applies to each pressure considered.

Further information on pressures arising from marine activities is provided on the Joint Nature Conservation Committee’s website. This can be used to help assess the sensitivity of the marine habitats present in the ZoI to the activities associated from your development. This in turn may identify a need for further work to inform the EcIA.

3.2.7. Selecting ecological parameters

Ecological parameters describe aspects of the structure and function of a biological community. The range of potential ecological parameters is extensive and includes such things as:

- Habitat extent and distribution
- The number of taxa
- Species diversity

- Biomass
- The biotic functional groups within a community
- Age/size distribution within a population

Selecting ecological parameters for marine habitats can be a complex process. This is true for both benthic habitat characterisation and for monitoring. There are additional considerations for monitoring with the ecological parameters referred to as 'indicators' (see Section 4.2.1). For an explanation of the different types of indicators (i.e. 'state' or 'pressure' indicators) see Noble-James *et al.* (2017).

Selection of appropriate ecological parameters for benthic habitat surveys depends on the habitat in question, the usefulness of the parameter in terms of EcIA and the potential pressures arising from a proposed development, and the practicability of collecting data for the parameters. Information about ecological parameters and indicators specific to particular benthic marine habitats is provided in the individual habitat and species chapters of this guidance (GN030a-h).

Once you have identified potential ecological parameters for the benthic habitat survey, consideration of the following should help finalise the selection:

- The purpose of the survey (i.e. as part of site characterisation; to also provide a baseline for future monitoring; for during and post-construction/activity monitoring)
- The type of predicted impact (e.g. point source; gradient)
- The scale of predicted impact

3.2.8. Design options for benthic marine habitat characterisation surveys

Habitat-specific information on survey design is provided in the individual habitat and species chapters of this guidance (GN030a-h). Additional information on survey design is available in Chapter 2 of the Marine Monitoring Handbook (Davies *et al.* 2001) which includes a range of options for survey design. Further guidance is also available in more recent sources including Ware *et al.* (2011) and Noble-James *et al.* (2017). It should be noted that some of the technical details in the Marine Monitoring Handbook (Davies *et al.* 2001) have been superseded due to advances in technology. However, it remains a comprehensive and widely used guidance document covering a diverse range of survey methods and survey and monitoring requirements.

It is intended that there will be further work carried out to improve the coverage and content of the **Marine Monitoring Handbook, i**n particular, updates to a range of Procedural Guidelines from Section 6 of the handbook. Further information on this is provided on the relevant page of the JNCC website.

Characterisation surveys of benthic habitats may be:

- Grid-based (especially where existing data are sparse for a location, as it provides a broad coverage across the ZoI)
- Stratified, with stations targeted to different habitats or sub-habitats across the ZoI

Stratifying sampling will account for natural spatial variability in habitat types (e.g. sediment types if considering benthic sediments) and will ensure data are collected for the range of

communities expected to be present within the project ZoI. For this approach to be applied, however, there must be prior accurate data for the distribution and extent of habitats and sub-habitats of interest in the survey area (e.g. suitable acoustic survey data).

Once you have identified habitats or sub-habitats for stratification, you can determine the number of stations to be allocated to each, and their positions can be randomly allocated within the specific substrate types. This will ensure statistical robustness of subsequent statistical analyses. It is also possible to select 'representative' station locations across known sediment types (judgement / selective sampling), however, this requires a high level of confidence in the habitat mapping forming the basis of the allocations and it has implications for statistical validity depending on the analyses to be conducted. Your proposed design approach should be developed based on these factors.

3.2.9. Control sites in the context of benthic habitat characterisation surveys

Control sites (also known as reference sites) are sampled to collect information on natural changes to habitats and species outside the ZoI of a development or activity. This information can then be compared to any changes measured within the ZoI which may have been caused by the development or activity. Control sites may be sampled as isolated habitats in their entirety (e.g. a control reef) or may be assessed by sampling at multiple stations distributed across the site (i.e. control stations).

Control sites are primarily used in monitoring surveys (section 4). However, there may be circumstances where the baseline information collected for habitat characterisation can also act as a temporal point for future monitoring requirements. In such situations the control sites need to be taken into account in the design of the benthic habitat characterisation surveys.

Whilst NRW Advisory acknowledges that this approach may be appropriate in some instances, in general we would advise against this. Instead, we advise that sites for monitoring (including control sites) are identified once the benthic habitat characterisation has been completed. This is because the selection of monitoring sites needs to be related to any specific monitoring requirements that are determined through the EcIA and subsequent processes These requirements are generally not known at the time the benthic habitat characterisation survey is planned and implemented. Sites selected for benthic habitat characterisation may not be appropriate to address the specific monitoring requirements.

3.2.10. Within-station replication

Within-station replication enables robust statistical analyses to be applied to multiple sampling events. It is a technique which is generally an integral aspect of monitoring (Section 4) and is used in order to detect change over time. However, for different reasons, it is an approach that may also be recommended for habitat characterisation, where its relevance will vary depending on the habitat being surveyed. For example, it is commonly applied for surveys of subtidal sediments (e.g. obtaining replicate grab samples at a single station).

Some advantages of within-station replication in the context of benthic habitat characterisation surveys are:

- Replicate data at stations are useful for gaining an understanding of small-scale variation in community composition in order to inform EcIA;
- Increased confidence when assigning a habitat or biotope based on the analysis of sample data at a single station; and
- Increased area of habitat sampled compared to single samples at the same number of stations, thereby increasing the chances of detecting rare taxa, species of conservation or commercial importance, and non-native species

The value of replication in terms of characterising communities is reduced, however, where communities are relatively homogeneous across very small spatial scales.

In terms of benthic habitat characterisation, some surveys might be better served by an increased number of sample stations but no replication at each station. This allows for obtaining data across a greater geographical area based on the acquisition of the same number of samples. This particularly applies to large-scale developments/activities with an extensive survey area. However, as commented on above (section 3.2.9), it can sometimes be beneficial to deliberately design a habitat characterisation survey in order that it can become part of a future monitoring station array. In this instance it would be important to consider collecting within-station replicates in line with expectations for the subsequent monitoring programme.

4. Monitoring

Summary

Monitoring needs to have a defined purposed, with clear and achievable objectives. The outcomes of habitat characterisation surveys and subsequent EcIA will inform the monitoring approach to be applied. The design of a monitoring programme for any proposed marine development/ activity will be governed by the nature of the activity itself and any requirements for monitoring, for example, set by the regulator as a condition of a license.

The investigative monitoring technique is the one most likely to be applied for assessing impacts on benthic habitats due to marine activities (Kröger & Johnston, 2016, included in Noble-James *et al.*, 2017); this approach is used to investigate the cause of change to benthic habitats to inform management needs

The outcomes of the benthic habitat characterisation survey and subsequent EcIA will inform the monitoring approach to be applied.

A successful monitoring programme relies on:

- Defining suitable hypotheses
- Establishing if trigger levels are required and, if so, what parameters they should relate to
- Determining the appropriate sampling effort to achieve an acceptable power to detect change
- Selecting a suitable design option (grid based, simple random sampling, stratified random sampling, BACI, BACIPS, MBACI, within-station replication)
- Identifying suitable control stations, if needed

The following sections provide an overview of what you need to consider if you have to design and implement a benthic marine habitat monitoring programme for your proposed development or activity. References to further information that you may find helpful are also provided. The information presented below deliberately considers monitoring in both a broader context as well as specifically in relation to monitoring requirements that may arise in relation to EcIA and regulatory development control. This is in order to:

- Present general principles that you need to consider when designing and undertaking monitoring; these are expanded on in the habitat-specific approaches and methods provided in the other chapters of this guidance (GN030a-h)

- To provide a broader understanding of some ongoing programmes of monitoring that may be relevant and useful for you to know about when formulating monitoring proposals for a specific development or activity.

4.1. Aims of monitoring for benthic habitats

The term ‘monitoring’ has a very broad application. Monitoring programmes may be put in place for a number of different reasons both within the requirements of regulatory development control. For example:

- Routine monitoring of equipment function or monitoring compliance with license conditions
- Much broader application such as long-term monitoring outwith any development proposals in order to determine the condition of a habitat or species over time in order to comply with national or international legislation

For the purpose of this guidance, the main objective of a monitoring programme for benthic marine habitats in the context of EcIA and regulatory development control, is to detect whether desired environmental conditions for any given habitat and its associated species are being exceeded in a way that requires some form of management measure to be implemented to prevent further negative change, and/or re-instate the required environmental status of the habitat.

If you are a developer, an important consideration for you during the initial stage of EcIA is to decide whether and how to monitor impacts associated with the development, in order to validate predictions made in the environmental assessment. You may decide to propose some degree of ecological monitoring as part of your application and this may include monitoring benthic marine habitats. Based on the evidence submitted with your application, the regulator may also set their own requirements for monitoring in addition to any that you propose yourself. Monitoring requirements set by the regulator will generally be incorporated into the conditions of any permission that is issued.

For proposed developments that have the potential for more significant and widescale environmental impacts and where, at the time of determining a licence or consent, there remains uncertainty about the potential effects, an Adaptive Environmental Management Plan may be required. Monitoring of benthic habitats may be required to inform any such plan, with clear ecological thresholds set for the monitoring, and management actions identified to be implemented if thresholds are exceeded.

Monitoring can play an important role in helping to address gaps in the evidence base and to help inform applications for development proposals in other locations or future expansion of interests at the same site. You may propose to undertake monitoring that goes beyond that required through the regulatory consenting process in order to improve the evidence base and address uncertainties to inform potential future work. The information in this guidance is applicable to benthic habitat monitoring in this context as well.

The monitoring that may be required for a development generally consists of:

- Pre- development/activity monitoring (this provides a ‘baseline’ dataset).
- During development/activity monitoring
- Post-development/activity monitoring

These requirements can also be supplemented by additional monitoring, such as assessing the effects of an applied mitigation measure or activities associated with decommissioning or cessation of an activity towards the end of its lifespan.

The monitoring work itself involves repeat sampling to detect change (or lack of change) over time, in one or more survey parameters (indicators) and across one or more habitats or communities, when compared to baseline data.

4.2. Designing a monitoring programme for benthic marine habitats

The design of monitoring programmes depends on the specific requirements of the monitoring to be undertaken. For example, NRW undertakes monitoring in relation to:

- Its regulatory role, such as monitoring of adherence to consent or licence conditions
- In its role as an evidence gatherer, such as expanding knowledge and understanding about the natural environment to support assessments of the state of the Welsh environment and the condition of protected habitats and species in compliance with national and international environmental obligations

In relation to developments and activities monitoring can encompass a range of different requirements**:**

- Project-specific monitoring (for example, pre-, during and post-construction/activity monitoring).
- Monitoring the effects of mitigation, compensation and/or habitat enhancement measures specific to an activity
- Operational monitoring, with management measures implemented when trigger levels are reached for a given parameter. For example, exceedance of chemical concentration in the water column due to an outfall discharge

The targets set for any programme of monitoring depend on the intention of the monitoring. For example, we conduct monitoring in order to be able to assess the condition of habitats and species against conservation targets. As a developer, if you need to conduct project-

specific monitoring, the targets for that work will need to be determined in relation to the details of the proposed development or activity.

It is, however, useful for you to be aware of NRWs own programmes of monitoring as these may influence the design of your proposed monitoring in terms of compatibility with existing NRW data and data requirements. For example, if your project has the potential to affect a Special Area of Conservation you may be asked by the regulator to monitor the effectiveness of proposed mitigation measures. In such situations, trigger levels for the monitoring would need to be set so that they would enable detection of impact before this reached a level that would cause adverse effect on integrity of a SAC and its features. In these circumstances, it could be useful for your monitoring programme design to be compatible with NRW's feature condition monitoring methods and data. This could enable you to use your data alongside NRW's existing data and so benefit from a more substantial information base and improved understanding of the feature condition. Information about the marine ecological data that NRW collects, holds and uses is provided in our guidance note GN006 Marine ecology datasets for marine developments and activities (Natural Resources Wales, 2019).

It should be noted that when designing a benthic habitat monitoring programme, considerations relating to the conservation value of the habitats present and their sensitivity as outlined above in sections 3.2.2 and 3.2.6, respectively, are equally applicable.

The JNCC has recently produced specific guidance for monitoring marine benthic habitats (Noble-James *et al.* 2017). This guidance is focussed on assisting the development of monitoring programmes of benthic marine habitats in order to produce evidence against which the cause and direction of change in the marine environment can be evaluated. Such monitoring programmes can help provide information as to the appropriateness and effectiveness of management measures for benthic marine habitats. A lot of the information in Noble-James et al., 2017) is also relevant to monitoring in relation to coastal and marine activities, including:

- Guidance for types of monitoring
- Selection of parameters/indicators for monitoring
- How to use existing data
- Sampling unit size and replication
- Sampling designs
- Appropriate statistical analyses

Monitoring can be:

- Direct (e.g. collecting physical and/or remote sensing data), or
- Indirect (e.g. monitoring of pressures to infer habitat condition)

Monitoring objectives will generally correspond to one or more of the three monitoring types described in the UK Marine Biodiversity Monitoring Strategy (Kröger & Johnston 2016):

- Type 1 – Sentinel Monitoring of long-term trends
- Type 2 – Operational Monitoring of pressure-state relationships

- Type 3 – Investigative Monitoring to determine management needs and effectiveness

Sentinel monitoring aims to measure the rate and direction of long-term change in marine habitats. This is the most likely monitoring method to be applied to an area of habitat to detect natural variation over time, in the absence of a known or experimental pressure (for example, the long-term monitoring of the status of features of a protected site). It is not generally considered applicable for assessing potential impacts of marine activities.

Operational monitoring can be used to explore the potential impacts of anthropogenic pressures on habitats and species. This type of monitoring, however, is generally applied to assess changes in habitats and species across a gradient of pressure from low to high. It is considered to be mainly relevant to developments and activities with such pressure gradients, such as a discharge from an outfall.

Investigative monitoring tests specific hypotheses to provide confidence when identifying cause and effect and is ***the most likely type of monitoring to be applied in relation to assessing potential impacts of marine activities*.** Any new activity represents a 'change to the status quo'. The monitoring is designed to detect differences in selected indicators following this change, with a time series established across pre-, during and post-construction/activity monitoring and the use of control stations. The pre-, during and post-construction/activity monitoring programme often consists of multiple survey events depending on numerous factors, including monitoring outcomes and project-specific licence conditions.
The investigative monitoring approach is also best suited to test state/pressure relationships and the efficacy of management measures as well as determining whether target thresholds have been exceeded and when adaptive management measures need to be implemented. In terms of developments/activities, the investigative monitoring approach could be applied to specifically monitor the effects of mitigation, compensation and habitat enhancement measures.

4.2.1. Selecting indicators for monitoring

In the context of monitoring, the term 'indicator' is used for the ecological parameters (section 3.2.7) that are selected as the focus for the monitoring programme. The robustness of the chosen indicators is vitally important to the relevance and, therefore, success of any investigative programme of monitoring for a particular development or activity. The indicators must be identified in a logical and non-subjective manner.

Indicators may be readily determined during the EcIA process as the detail of potential likely impacts and any requirements for mitigation and monitoring are identified. The list below provides a suite of criteria to consider in the selection of appropriate indicators for monitoring and Figure 1 provides a stepwise process that could be applied to help determine the effectiveness, appropriateness and validity of potential indicators for marine habitats.

- **Sensitivity** - Does the indicator allow detection of any type of change against background variation or noise?
- **Accuracy** - Is the indicator measured with a low error rate?

- **Specificity**- Does the indicator respond primarily to a particular human pressure, with low responsiveness to other causes of change?
- **Simplicity** - Is the indicator easily measured?
- **Responsiveness** - Is the indicator able to act as an early warning signal?
- **Spatial applicability** - Is the indicator measurable over a large proportion of the geographical area to which it is to apply e.g. if the indicator is used at a UK level, is it possible to measure the required parameter(s) across this entire range or is it localised to one small area?
- **Management link** - Is the indicator tightly linked to an activity which can be managed to reduce its negative effects on the indicator i.e. are the quantitative trends in cause and effect of change well known?
- **Validity** - Is the indicator based on an existing body or time-series of data (continuous or interrupted) to allow a realistic setting of objectives?
- **Communication** - Is the indicator relatively easy to understand by non-scientists and those who will decide on their use?

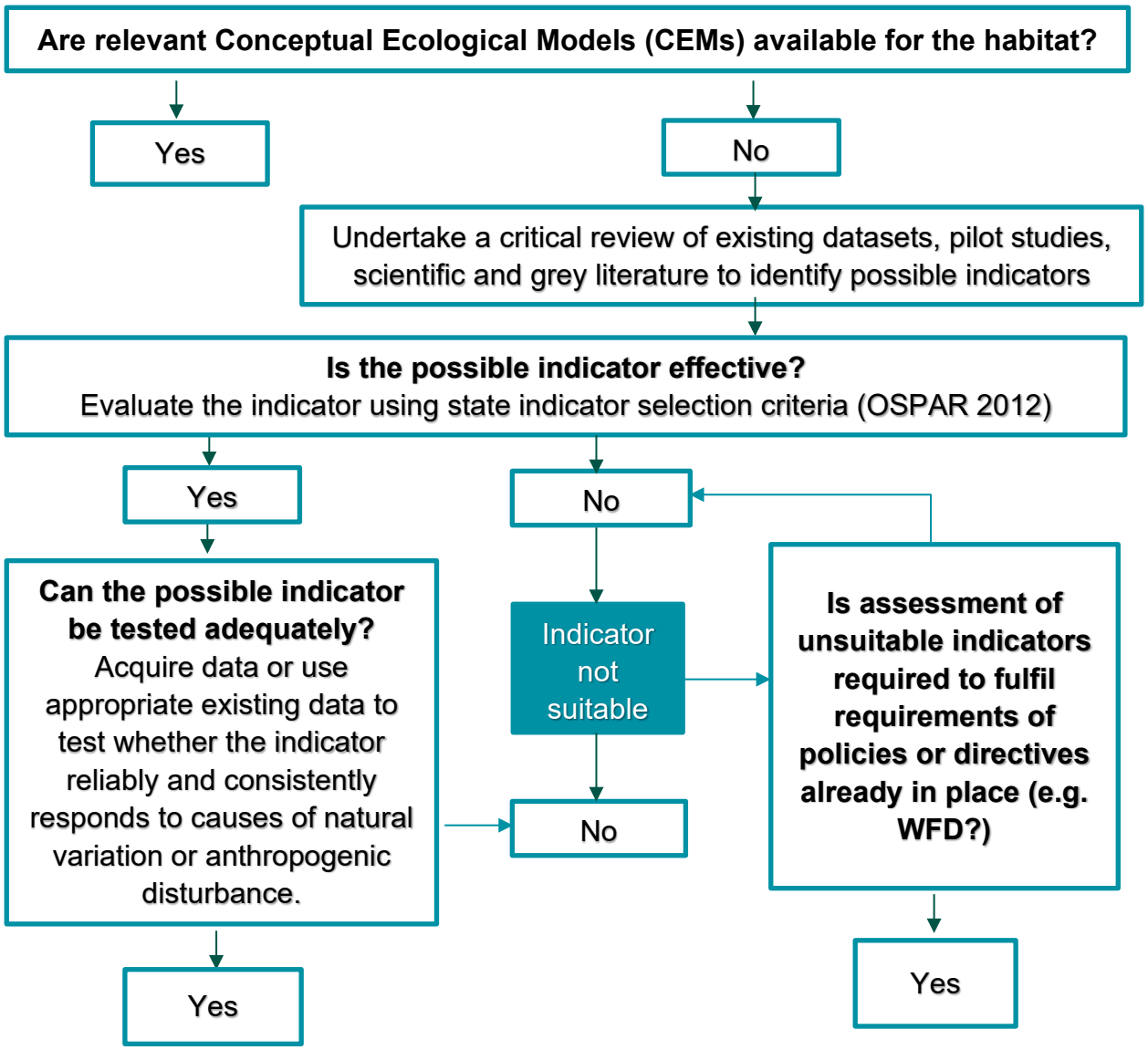

Figure 1. Selecting indicators: a process to determine the effectiveness, appropriateness and validity of potential indicators for protected marine habitats based on recommendations set out by Noble-James *et al.* (2017).

4.2.2. Defining monitoring hypotheses

Hypotheses are predictions which are set up to be challenged or validated by data and are an essential precursor to developing and effective monitoring programme. In ecological monitoring they are generally framed to detect change in a selected parameter over time, and to determine if any change observed is outside of normal expectations. Hypotheses help to define the evidence that is required to answer specific questions and meet the objectives of the monitoring, such as indicating potential effects, or absence of effects, of an activity on a marine habitat.

A successful monitoring programme depends on developing suitable hypotheses that can be tested effectively. Hypotheses should be defined before deciding the sampling design, to avoid ambiguity about what is actually being measured (Addison 2011). In relation to EcIA and regulatory development control, hypotheses would need to relate to predicted impacts from a development.

Hypothesis testing is a method of statistical inference which generally involves the comparison of two datasets (e.g. pre- and post-construction data). A null hypothesis (H_0) proposes no relationship between two data sets. An alternative hypothesis (H_1) is proposed for the statistical relationship between the two data sets, and this is tested against the null hypothesis. For example, hypotheses could be:

H_0: Abundance of a particular species will ***remain the same*** within a particular habitat following construction of a development
H_1: Abundance of a particular species will ***change*** within a particular habitat following construction of a development

Formulating and testing hypotheses about indicator response is central to evaluating whether any change has occurred over time (Addison, 2011; Eleftheriou, 2013). Noble-James *et al.* (2017) provides further detail on defining suitable hypotheses, and various considerations including the potential for Type I error and Type II:

- **Type I error:** A false positive error that occurs when a significant effect is detected. In reality there is no significant effect, and so there is erroneous rejection of the null hypothesis.

- **Type II error:** A false negative error that occurs where no significant effect has been detected. In reality there has been a significant effect, and so there is an erroneous acceptance of the null hypothesis.

4.2.3. Trigger levels

Key thresholds known as ‘trigger levels’ can be set for specific indicators in order to help assess whether impacts are evident on a given indicator over the course of a monitoring programme.

Depending on the proposed development or activity and likely impacts arising from it, mitigation measures may be proposed as a way of reducing the predicted significance of a particular effect on a given receptor. In these situations, threshold trigger levels for an indicator relevant to a given effect and receptor can be identified.

Where mitigation measures and monitoring are required as a condition of a permission, trigger levels will generally need to be set. For example, this could be as part of an Adaptive Management Plan (e.g. Lindenmayer & Likens 2009). If an agreed trigger level for a specific indicator has been reached or exceeded, management action will generally be required in order to reduce the impact to a level that is considered to be acceptable.

If you need to undertake monitoring in relation to your proposed development or activity, you will need to determine what indicators should be measured and what level of change would be a trigger for a management action. Your monitoring proposals would need to be agreed with the regulator.
Appropriate and measurable trigger levels will be associated with defined hypotheses and will involve a certain pre-determined level of change in a given parameter. They will vary considerably across projects, depending on the scale of the activity and its potential impacts.

4.2.4. Determining appropriate sampling effort

For monitoring purposes, multiple stations will be required within different habitat types located within the ZoI and within control sites outside the ZoI.

If Primary and Secondary Impact Zones are identified for your development or activity, the number of stations in both of these will need to be determined, taking into account the different habitat types present within each. The Primary Impact Zone is the immediate footprint of the development activity where the proposed works will occur; the Secondary Impact Zone is the area where effects occur that extend beyond the immediate footprint of the development or activity. These terms are most commonly used in relation to dredging activity but are applicable in other contexts where there are near- and far-field effects.

Where previous biological data are available for a location (e.g. historic data, or data from the benthic habitat characterisation surveys), power analysis can be applied as a useful statistical tool in the design of robust experiments and monitoring strategies. The technique can use the degree of variability across previously collected data to provide an estimate of sampling effort needed (i.e. how many stations need to be sampled) to demonstrate a statistically significant effect of a pre-determined size on a specific parameter.

Several factors influence the power of a monitoring programme including:

- The number of samples

- The inherent variability in the system (high variance leads to low power)
- Effect size (the magnitude of the change occurring)

A large effect size, in a system where the inherent variability is low, will require only limited sampling effort to detect the effect. A small effect size, in a system showing high variability, will be difficult to detect (Di Stefano, 2003).

It is therefore crucial to understand the power of a monitoring programme to detect a given change when:

- Deciding the sampling effort required for validating impacts predicted in EcIAs
- Evaluating the success of any mitigation, compensation and enhancement measures

An increase in sample size will always result in increased precision and power by reducing variance in the sample, but the relationship between power and sample size is curvilinear. As the sample size increases (often with accompanying cost) there are diminishing returns beyond a certain point on the power continuum. Power analysis allows surveyors to determine where this point occurs, and simultaneously maximise statistical robustness and cost-effectiveness.

Note: to conduct power analysis it is necessary to have historic data for the parameters of interest in the survey area. You could potentially obtain such data from the benthic habitat characterisation survey outputs (Section 3) or from other previous studies in the area.

Key considerations for power analysis

The approach to the power analysis will be influenced by a number of factors, and the monitoring programme must make decisions on:

- The parameters/indicators for conducting the power analysis. For example, for subtidal sediments univariate descriptors may be used, such as number of taxa, or number of invertebrate individuals
- The type of statistical analyses which will be conducted to test the hypotheses
- The level of change in the parameters which the monitoring programme will be required to detect. This level of change will vary from one monitoring programme to another and will depend on the nature of the parameters and of the effects being tested. If monitoring is being undertaken as a condition of a consent then the parameters to be monitored and the monitoring methods will need to be agreed with, and authorised by the regulator

The number of stations required to detect a desired level of change may sometimes be unfeasible due to logistic or cost restraints. If this is the case, you will need to consider alternative solutions which may require discussion with the regulator, and bear in mind that these could result in an increase in the detectable effect size, or reduced confidence in the conclusions reached based on the statistical analyses. Further detail about the range of considerations associated with power analysis is provided in Noble-James *et al.* (2017).

4.2.5. Monitoring programme design options

The design of a programme of monitoring survey will depend on its objectives as outlined in section 4.1 above. Chapter 2 of the Marine Monitoring Handbook (Davies *et al.*, 2001) includes a range of options for monitoring survey design. Guidance is also provided in more recent sources, including Ware & Kenny (2011) and Noble-James *et al.* (2017).

Design options include the following:

- Grid based
- Simple random sampling
- Stratified random sampling

Monitoring surveys need to consider whether stations should have fixed locations for all future monitoring surveys or, if they should be randomly allocated for each survey (using the same criteria each time). The decision will depend on the specific monitoring requirements of an activity and will influence which statistical analyses may be suitable for data analysis. The use of fixed locations has a range of advantages and disadvantages Noble-James *et al.* (2017) provides more detail on when this approach should be considered.

The outcomes of the benthic habitat characterisation survey and subsequent EcIA will inform the monitoring approach to be applied. For example, licence conditions for an activity could be associated with ongoing targeted monitoring of a particular habitat of conservation importance (as opposed to ongoing broad monitoring of the whole of the benthic habitat characterisation survey area). Or licence conditions could focus on detecting change associated with a specific expected operational pressure.

Monitoring of the effectiveness of mitigation measures may be required by the regulator together with identifying actions to take if agreed levels are exceeded. This will involve identifying the receptors and indicators to be monitored and, where possible or practicable, establishing key trigger levels. If compensation measures are required for a development there may need for a monitoring programme to determine the effectiveness of these measures; again, this will involve identifying the receptors and indicators to be monitored.

4.2.5.1. BACI design and control sites and stations

Variations of the Before-After-Control-Impact (BACI) design are usually integral to activity-related monitoring.

The basic BACI design involves sampling before and after an event such as the construction of a development. This approach requires control sites or stations outside the ZoI. Data collected from these stations will allow an appraisal of natural local variability in habitat characteristics and attributes, compared to any changes found within the development or activity site. This will determine if there have been any significant changes in marine habitats due to the development or activity.

More advanced BACI Paired Series (BACIPS) designs involve repeated sampling of the control and impact sites or stations at the same times (or as close together as is feasible), so that shared temporal effects may be identified (Stewart-Oaten *et al.*, 1986). This

approach can provide more powerful estimates of impact accounting for many extraneous sources of 'noise' which limit other designs.

The BACIPS design can be further developed to include multiple control and/or impact stations, sampled at multiple times before and after the event or impact (MBACI) (Keough & Mapstone, 1995). This is the most likely approach to be applied to activity related monitoring (albeit with limited sampling before the event or impact). If the event being monitored results in actual changes, the difference between the impact and control stations will be greater than the differences between control stations.

Although it is statistically desirable to investigate equal numbers of impact and control locations (a symmetrical design), this may not always be possible. This may be due to difficulties in finding suitable control stations (see below), or due to financial or logistic constraints. In these circumstances, an asymmetrical design should be employed with multiple control stations (Underwood, 1990 and 1992). The number of control stations should be determined on a project-specific basis.

Where habitats are highly mobile (e.g. some sandbanks), or ephemeral (e.g. some *Sabellaria* reefs), monitoring results should be interpreted with caution. It is likely that the substrates and community composition of such habitats will change naturally within both the control and impact areas. It may not, therefore, be possible to categorically attribute an improvement or decline in condition as being due to the event being monitored over reasonable time periods. The individual habitat chapters GN030a-GN030h contain more detail of the most appropriate type of monitoring in such instances.

4.2.5.2. Control site locations

Identifying suitable control sites is an essential component of an effective BACIPS/ MBACI design.

Control sites should:

- Have comparable environmental conditions to those of the impact site (including, for example, sediment type, depth, organic inputs)
- Ideally be well mapped, particularly where comparable substrates are likely to be isolated or limited in extent (such as a rocky outcrop), although high resolution maps are less critical where substrates are likely to be homogeneous
- Be outside of, but as close as possible to the ZoI of the development or activity

Further considerations in relation to optimal requirements for control sites are outlined in Table 7 of Noble-James *et al.* (2017).

Finding suitable control sites can often be difficult. For example, habitats may be locally rare, or there may be gradients in environmental parameters such as changes in salinity along an estuary, or considerable changes in depth between the ZoI of the proposed activity and surrounding areas. Despite efforts to select sites with similar physical and ecological characteristics, there may still be spatial and temporal differences between the impact and control sites which are unrelated to the development or activity.

BACIPS/MBACI results should therefore be interpreted with a degree of caution (Noble-James *et al.*, 2017). Table 7 of Noble-James *et al.* (2017) indicates mitigating measures

which can be considered when the principles for control site selection cannot be met. The locations of control sites should take into account the requirements outlined above and will vary from project to project.

Sites in the ZoI and the control areas will ideally be sampled as close together in time as possible. This will avoid any chance that an environmental change or disturbance event, unrelated to the development or activity, occurs between collection of 'control' and 'impact' data.

4.2.5.3. Within-station replication

It is important to consider the amount of replication required at individual stations for project-specific monitoring programmes.

Within-station replication is necessary for applying the robust statistical techniques which are required to detect change in community characteristics across stations and sampling events. It also increases the likelihood that rare or sparsely distributed taxa will be recorded at a given station. Replicates may be analysed to evaluate within-station variance and aggregated for comparison with other stations across the survey area.

The need to understand small-scale variability through within-station replication must be balanced with the requirement to collect data at a wide range of separate stations. In advice to JNCC, Holtrop & Brewer (2013) recommended that when resources are limited, collecting samples from a wider range of sampling locations should be prioritised over within-station replicates. However, this approach is likely to lead to a reduced understanding of localised variation. For monitoring related to marine activities it is generally recommended that within-station sampling is conducted where resources allow (Noble-James, *et al.*, 2017. The decision on whether to collect replicate samples within stations, and the amount of replication, will depend on the monitoring objectives for the development or activity and the statistical robustness required of the data, and should be considered on a case-by-case basis.

The concept of spatial pseudoreplication can be applicable to replicates within sampling units. If multiple replicates have been acquired from a single sampling point, they can be analysed (for example, via cluster analysis) to identify differences between replicates at a given station. This will help to understand very small-scale changes in community characteristics. When comparing data across stations, however, they should not be treated as separate sampling units for certain statistical tests. In these instances, replicates should be pooled, and a mean value calculated to provide a single value for each sampling unit to avoid dependency issues. Further discussion around pseudoreplication is provided in Noble-James *et al.* (2017).

We recommend that you discuss the potential for pseudoreplication due to within-station replication with a statistical specialist, based on the monitoring survey design, the proposed statistical analyses to be applied and the objectives of the monitoring programme.

4.3. Frequency and duration of monitoring

The frequency of any monitoring should be considered and agreed at the start of the monitoring programme. In reality, the sampling design and frequency will depend

considerably on the reason for the sampling, and environmental and logistical considerations. The design of monitoring surveys should be bespoke to specific projects and monitoring objectives for the particular habitat.

Pre-construction or pre-activity (baseline) monitoring can usually have a duration of one to two years and, during construction/activity, there would be monitoring each year. However, these requirements will depend on the objectives of the monitoring programme and the expected response to the pressure.

Depending on the results of the monitoring and the scale of the development or activity, there may be a number of years of post-construction/activity monitoring with annual frequency potentially decreasing over time. For example, there may be annual monitoring for three years which then reduces to monitoring every three or five years, or until sufficient data are gathered to have determined any effects of the development or activity. With this approach, data gathered can encompass an assessment of short-term and long-term effects.

It should be noted that for benthic monitoring, a single survey each year would likely be sufficient, but the number of sampling events each year should be based on the types of habitat present, level of heterogeneity of habitat and monitoring objectives.

In addition to frequency and duration of monitoring, consideration also needs to be given to the seasonality of when the monitoring occurs and any requirements for this to be adhered to throughout the length of the monitoring programme.

4.4. Data analysis and interpretation

The most suitable approach for data analysis and interpretation needs to consider a variety of factors such as whether data are being analysed for a habitat characterisation survey or monitoring programme, and the approach and methods used. Further detail is provided in Noble-James *et al*. (2017).

The specific habitat chapters (GN030a-h) go into more detail about data analysis and interpretation relevant to the individual habitats, but some general considerations are covered briefly below.

4.4.1. Metrics for biotic communities and species assemblages

Analyses will involve calculating a range of appropriate metrics to characterise biotic communities or assemblages. These could include abundance, biomass, taxon richness, evenness, diversity, taxonomic distinctness, and biological traits metrics. Distributional techniques can also be used that provide visual outputs such as a curve or histogram, including ranked species abundance curves, species accumulation curves and abundance-biomass comparison curves (Noble-James *et al.,* 2017).

4.4.2. Statistical analysis

Monitoring data should be subject to statistical analysis and interpretation to test the hypotheses set out at the design stage. A wide range of suitable univariate and multivariate analysis and mapping techniques are available for analyzing data relating to

marine habitats. As a result, those chosen are likely to vary markedly between projects depending on the purpose and design of the monitoring and nature of the data collected. The type of analysis should be determined on a project-specific basis and should be clearly defined before sampling commences as part of the survey design considerations.

Understanding why statistical analyses are being conducted and what information is required allows the most appropriate statistical test and methods for interpretation and analysis to be selected and ensure that the data will meet the requirements for the proposed analytical approach. Data may need to be subjected to truncation, transformation or standardisation before analysis.

The most applicable statistical analyses for most monitoring projects are those associated with 'identifying differences between groups', although some of the techniques outlined in Noble-James *et al*. (2017) for 'identifying patterns in multivariate community data' are also applicable. These include the ANOSIM routine and PERMANOVA, which is for more complex analyses such as testing for multiple variables (e.g. temporal and spatial changes, and Before After Control Impact (BACI) designs).

In addition, to assess potential relationships between biotic data and environmental data, approaches such as BIO-ENV analysis (also referred to as BEST analysis when combined with the BV-STEP stepwise selection procedure) can be used to find the 'best' match between patterns in biological communities and associated environmental variables by exploring different variable combinations and ranking the best combinations according to their correlation coefficients.

We recommend that the statistical approaches you chose to employ are selected in consultation with an experienced statistician on a project-by-project basis.

4.4.3. Use of mapped habitat data

Marine habitat data may be presented as detailed survey maps, typically using spatial mapping software packages, with the most common software typically being ESRI ArcGIS.

Locations and extents of change in habitat type can be detected by comparing mapping outputs within a GIS with mapping datasets obtained during previous monitoring (compatibility of monitoring data and software should be ensured for sampling events across a monitoring programme).

4.4.4. Aerial imagery

With aerial imagery, specialist image processing software should be used to perform the following functions:

- Geometric image correction
- Radiometric image correction
- Quality control image data before, during and after download

The pre-processing functions above are used to create colour-balanced, distortion-free aerial imagery. The processed imagery and associated flight log data are imported into specialist proprietary photogrammetric software, to be mosaiced and orthorectified to

generate seamless high resolution georeferenced orthomosaics. The imagery should be aligned using pixel-matching algorithms which identify common features between each image pair. The post-processed GPS data from the aircraft or drone is then used to triangulate the block, creating a continuous model of the site. Once the initial triangulation is complete, any Ground Control Point (GCP) data captured in the field can be imported into the block to enhance the accuracy of the model. A final seamless, accurately georeferenced image mosaic should then be produced.

4.4.5. Acoustic data

The processing of acoustic / geophysical data collected for subtidal habitats (such as multibeam and side scan sonar data) can be complex and will vary markedly depending on the method of collection. A variety of guidance is available (such as. Populus & Perrot, 2007; Henriques *et al.*, 2012; Plets *et al.*, 2013; IMCA, 2015) and should be followed where possible. Further information on these methods and interpretation of data is provided in individual habitat chapters of the guidance where these methods are relevant (for example GN030c *Modiolus modiolus* reefs, GN030d *Sabellaria* spp. reefs and GN030h subtidal sediments). All processing should be undertaken to International Hydrographic Organisation 1A standard (IHO 2008).

5. References

Addison P. 2011. A global review of long-term Marine Protected Area monitoring programmes: The application of a good framework to marine biological monitoring. JNCC Report No. 455.

Connor DW, Allen JH, Golding N, Howell KL, Lieberknecht LM, Northen KO, Reker JB. 2004. The marine habitat classification for Britain and Ireland Version 04.05. JNCC, Peterborough.

Davies J, Baxter J, Bradley M, Connor D, Khan J, Murray E, Sanderson W, Turnbull C, Vincent M. 2001. Marine Monitoring Handbook March 2001 (Jon Davies, J Baxter, M Bradley, D Connor, J Khan, E Murray, W Sanderson, C Turnbull, and M Vincent, Eds.).

Defra. 2014. Marine Strategy Part Two: UK Marine Monitoring Programmes.

Defra. 2015. Marine Strategy Part Three: UK programme of measures https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/486623/marine-strategy-part3-programme-of-measures.pdf.

Di Stefano J. 2003. How much power is enough? Against the development of an arbitrary convention for statistical power calculations. *Functional Ecology* 17, 707-709.

EEA (European Environment Agency). 2017. EUNIS habitat type hierarchical view.

Eleftheriou A. 2013. Methods for the Study of Marine Benthos - Fourth Edition.
Noble-James T, Jesus A, Fionnuala M. 2017. Monitoring guidance for marine benthic habitats. JNCC Rep No: 598:119.

Henriques V, Mendes B, Pinheiro LM, Concalves D, Long D. 2012. Recommended Operating Guidelines (ROG) for sidescan sonars. MESH Atlantic.

Holtrop G, Brewer M. 2013. Provision of statistical evidence to the Marine Protected Sites monitoring project. JNCC Report No. 493.

IHO. 2008. IHO standards for hydrographic surveys. 5th Edition. Special Publication No. 44.

IMCA. 2015. Guidelines for the use of multibeam echosounders for offshore surveys. International Marine Contractors Association.

JNCC. 2016. Assessing the contribution of Welsh MPAs towards an ecologically coherent MPA network in 2016.

Keough MJ, Mapstone BD. 1995. Protocols for Designing Marine Ecological Monitoring Programs Associated with BEK Mills. National Pulp Mills Research Programme, Technical Report No. 11 CSIRO, Canberra.

Kröger K, Johnston C. 2016. The UK Marine Biodiversity Monitoring Strategy.

Lindenmayer DB, Likens G. (2009) Adaptive monitoring – a new paradigm for long-term studies. *Trends in Ecology and Evolution* 24 (9), 482-486.

Noble-James T, Jesus A, Fionnuala M. 2017. Monitoring guidance for marine benthic habitats. JNCC Report No: 598:119.

Natural Resources Wales. 2019. Marine ecology datasets for marine developments and activities: Marine ecology data owned or recommended by NRW and how to access it. Natural Resources Wales, Bangor.

OSPAR. 2012. OSPAR's MSFD Advice Manual on Biodiversity Approaches to determining good environmental status, setting of environmental targets and selecting indicators for Marine Strategy Framework Directive descriptors 1, 2, 4 and 6. Prepared by the OSPAR Intersession.

Parry MEV, Howell KL, Narayanaswamy BE, Bett BJ, Jones DOB, Hughes DJ, Piechaud N, Nickell TD, Ellwood H, Askew N, Jenkins C, Manca E. 2015. Report 530. A Deep-sea Section for the Marine Habitat Classification of Britain and Ireland.

Plets R, Dix J, Bates R. 2013. Marine Geophysics Data Acquisition, Processing and Interpretation: Guidance notes. https://pure.ulster.ac.uk/en/publications/marine-geophysics-data-acquisition-processing-and-interpretation-3.

Populus J, Perrot T. 2007. MESH Recommended operating guidelines (ROG) for single-beam echosounder surveying.

Stewart-Oaten A, Murdoch W, Parker K. 1986. Environmental impact assessment: "Pseudoreplication" in time? *Ecology* 67, 929–940.

Tillin HM, Hull SC, Tyler-Walters H. 2010. Development of a sensitivity matrix (pressures-MCZ/MPA features). Report to the Department of the Environment, Food and Rural Affairs from ABPmer, Southampton and the Marine Life Information Network (MarLIN) Plymouth: Marine Biological Association of the UK., Defra Contract no. MB0102 Task 3A, Report no. 22., London, 145 pp.

Tillin HM, Tyler-Walters H. 2014. Assessing the sensitivity of subtidal sedimentary habitats to pressures associated with marine activities. Phase 2 Report – Literature review and sensitivity assessments for ecological groups for circalittoral and offshore Level 5 biotopes. JNCC Report No. 512B, 260 pp. Peterborough, Joint Nature Conservation Committee (JNCC), 260pp. (Report no. 512B).

Underwood AJ. 1990. Experiments in ecology and management: Their logics, functions and interpretations. *Australian Journal of Ecology* 15, 365-389.

Underwood AJ. 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.

Ware SJ, Kenny AJ. 2011. Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites. 2nd ed. Marine Aggregate Levy Sustainability Fund.

Ware SJ, Kenny AJ, Curtis M, Froján CB, Cooper K, Reach I, Bussell J, Service M, Boyd A, Sotheran I, Egerton J, Pearce LSB. 2011. Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites. Marine Aggregrates Levy Sustain Fund 2, 80.

Wyn G, Brazier P, Birch K, Bunker A, Cooke A, Jones M, Lough N, McMath A, Roberts S. 2006. Handbook for Marine Intertidal Phase 1 Biotope Mapping Survey. Report from Countryside Council for Wales.

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Natural Resources Wales
Cambria House
29 Newport Road
Cardiff
CF24 0TP
0300 065 3000 (Mon-Fri 8am-6pm)
enquiries@naturalresourceswales.gov.uk
www.naturalresourceswales.gov.uk