Cyfoeth Naturiol Cymru
Natural Resources Wales

Guidance Note

Benthic habitat assessment guidance for marine developments and activities

A guide to characterising and monitoring horse mussel *Modiolus modiolus* reefs

Reference number: GN030c

Document Owner: Marine Programme Planning and Delivery Group

What is this document about?

This guidance sets out our methods and approaches for survey and monitoring of horse mussel *Modiolus modiolus* reefs where such work is required to support environmental and ecological impact assessments for developments and activities in or near Welsh waters.

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

Version History

Document Version	Date Published	Summary of Changes
1.0	[06-2019]	Document published
2.0	[02-2021]	Review after 1 year of publication

Review Date: [02-2022]

To report issues or problems with this guidance contact Guidance Development

Contents

1. Introduction and summary
    - 1.1. What are *Modiolus modiolus* beds and where are they found in Wales?
    - 1.2. The conservation importance of *Modiolus modiolus beds*
    - 1.3. What kind of developments and activities might affect *M. modiolus* beds?
    - 1.4. Existing data and guidance for surveying and monitoring *Modiolus modiolus* beds
    - 1.5. Survey and monitoring design
    - 1.6. Survey and monitoring methods and analysis
2. Habitat introduction
    - 2.1. Overview
    - 2.2. Sub-habitats
    - 2.3. Extent/distribution in Wales
    - 2.4. Conservation importance
        - 2.4.1. Habitats Directive
        - 2.4.2. Marine Strategy Framework Directive
        - 2.4.3. OSPAR list of threatened and/or declining species and habitats
        - 2.4.4. Environment (Wales) Act 2016 Section 7 list of habitats/species of principal importance (previously NERC S42 lists)
        - 2.4.5. Marine and Coastal Access Act 2009
        - 2.4.6. Welsh Marine Protected Area Network
    - 2.5. Key potential pressures
    - 2.6. Sensitivity (resistance/resilience to pressures)
3. Existing guidance and data
    - 3.1. Common Standards Monitoring
    - 3.2. Marine Strategy Framework Directive
    - 3.3. OSPAR Monitoring Guidance
    - 3.4. MESH guidance
    - 3.5. NMBAQC guidance
    - 3.6. Data sources
4. Survey and monitoring design
    - 4.1. Existing data
    - 4.2. Selecting ecological parameters
    - 4.3. Benthic habitat characterisation
        - 4.3.1. Aims of benthic habitat characterisation surveys for *M. modiolus* beds
        - 4.3.2. Design of benthic habitat characterisation surveys for *M. modiolus* beds
    - 4.4. Monitoring
        - 4.4.1. Aims of monitoring programmes for *M. modiolus* beds
        - 4.4.2. Defining hypotheses and trigger levels
        - 4.4.3. Design of monitoring programmes for *M. modiolus* beds

4.4.4. Sampling timing, frequency and duration
4.4.5. Supporting environment
5. Survey and monitoring methods and analysis
5.1. Field methods
5.1.1. *Modiolus modiolus* bed parameters
5.1.2. Fieldwork Quality Control
5.2. Analytical methods
5.2.1. Geophysical data
5.2.2. Underwater imagery
5.2.4. Analytical Quality Control
5.3. Data analysis and interpretation
5.3.1. Habitat Characterisation and Monitoring
6. References

1. Introduction and summary

This guidance is one of a series of Benthic Habitat Assessment Chapters developed by Natural Resources Wales (NRW) for key habitats of conservation importance around Wales. It has been prepared by NRW with the initial document prepared under contract by APEM Ltd.

The guidance aims to assist developers in designing and undertaking robust benthic habitat characterisation surveys and monitoring of these habitats in the context of Ecological Impact Assessment, thereby helping streamline the regulatory review and consultation process.

This chapter will be relevant if you already have seabed habitat data and know that horse mussel *Modiolus modiolus* reef habitats are present, and you need to carry out habitat characterisation and/or monitoring of these reefs.

If you are unsure about the habitats present, you should refer to chapter GN030g which covers characterisation of subtidal habitats.

This habitat chapter (GN030c) is not intended to be used alone and should always be used in conjunction with the NRW Guidance Note GN030 and the Introductory chapter (GN030-intro).

1.1. What are *Modiolus modiolus* beds and where are they found in Wales?

The northern horse mussel *Modiolus modiolus* is a bivalve mollusc that can occur as single individuals or can form aggregations of live mussels referred to as *Modiolus modiolus* beds. These beds are biogenic reef structures and they provide an important habitat for a variety of other marine life. The mussels are long lived, and the beds are considered to be a persistent seabed habitat where they occur. Individual *M. modiolus* are relatively common in the subtidal, but *M. modiolus* beds (with typically 30% *M. modiolus* cover or more) are much more limited in their distribution. There are examples of where *M. modiolus* beds have been damaged or destroyed and have not, to date, recovered.

M. modiolus beds form in the subtidal on areas on soft, coarse and mixed sediment that become stabilised by the presence of the mussel bed. *M.modiolus* beds occur patchily and mainly in cold temperate coastal parts of the north-east Atlantic shelf seas. In Wales they are mainly present along the coastline of north and north-west Anglesey and Caernarfon Bay on the north coast of the Llŷn Peninsula, and potentially the outer areas of Cardigan Bay (see section 2.3 for more details).

1.2. The conservation importance of *Modiolus modiolus beds*

M. modiolus beds have a high biodiversity value, often supporting a rich and varied community of epifauna and infauna living on and in the mussel bed. They provide an important role in ecosystem functioning providing, amongst other things, nursery and feeding grounds for many species, including some commercially important fish and shellfish. The biodiversity and ecosystem role of *M. modiolus* beds is recognised through their protection under a range of national and international legislation, including:

- Habitats Directive
- Marine Strategy Framework Directive
- OSPAR Convention
- Environment (Wales) At 2016
- Marine and Coastal Access Act 2009

More information is provided in section 2.4.

1.3. What kind of developments and activities might affect *M. modiolus* beds?

Developments and activities that could affect this habitat during construction and/or operational phases include those involving actions that could result in:

- Direct removal of beds and physical damage to beds (for example from infrastructure developments, fishing activity)
- Changes to water quality (such as nutrient and organic enrichment, suspended solids)
- Changes to sediment transport dynamics, erosion/accretion regime, siltation and geomorphology
- Changes to hydrodynamic regime (including current speed)
- Introduction of invasive species
- Pollution and other chemical changes

Further detail relating to potential pressures from developments and activities on *M. modiolus* beds is provided in section 2.5.

1.4. Existing data and guidance for surveying and monitoring *Modiolus modiolus* beds

A brief summary of available information is provided in section 3. Key sources of existing data and guidance for surveying and monitoring *M. modiolus* beds are:

- Joint Nature Conservation Committee (JNCC): recent JNCC guidance for the monitoring of marine benthic habitats (Noble-James *et al*, 2017).
- Common Standards Monitoring: developed for site monitoring and assessment of protected sites (JNCC, 2004) and specific habitat guidance for reefs (JNCC, 2004a)
- Marine Monitoring Handbook (Davies *et al.* 2001).
- Guidance on selection of appropriate community indicators for *M. modiolus* survey in relation to monitoring requirements for the Marine Strategy Framework Directive (Fariñas -Franco *et al*., 2014).
- Guidance from OPSAR (2009) on a proposed approach for monitoring *M. modiolus* beds.
- Mapping European Seabed Habitats (MESH) and MESH Atlantic recommended operating guidelines for:
    - Swath bathymetry (Hopkins, 2007)
    - Side scan sonar (Henriques *et al.*, 2013)

    - Underwater video and photographic imaging techniques (Coggan *et al.*, 2007)
- Benthic monitoring survey design and planning and geophysical survey and methods (Ware & Kenny, 2011; Saunders *et al.*, 2011) – produced for work in relation to the aggregate industry and marine renewables but have wider application.
- North-East Atlantic Marine Biological Analytical Quality Control (NMBAQC):
    - Remote monitoring of epibiota using digital imagery (Hitchin *et al.*, 2015)
    - Analysis of remote underwater video footage and still images (Turner *et al.*, 2016)
- NRW Guidance GN006: Marine Ecology Datasets for marine developments and activities (Natural Resources Wales, 2019). Identifies data sources for subtidal habitat maps and provides information on the marine ecology data sets we hold and routinely use and how you can access them.
- Welsh government data portal 'Lle' and NBN Atlas Wales: data layers for *M. modiolus* beds in Wales.

1.5. Survey and monitoring design

The requirements for habitat characterisation survey and monitoring design are covered in section 4. The following provides a brief summary of key points:

- The aim of the habitat characterisation survey is to collate data to describe the *M. modiolus* beds within the survey area, identify any other habitats and/or species of conservation importance and provide an up-to-date ecological appraisal to inform Ecological Impact Assessment (EcIA).
- The habitat characterisation survey needs to ensure that the number of sample stations provides sufficient coverage of potential or known *M. modiolus* beds within the area likely to be affected by the proposed development or activity.
- The aims of any monitoring required for a proposed development or activity will depend on the potential impacts as identified through the EcIA and any conditions set by the regulator.
- The aims of the habitat characterisation survey and monitoring need to be clearly stated and the survey programmes tailored to deliver these requirements. This includes defining hypotheses and trigger levels for monitoring.
- A comprehensive desk-based review of all available existing data should be conducted prior to designing any habitat characterisation or monitoring. programmes. This will help determine the scope of survey that may be required
- If *M. modiolus* beds are known to occur in the proposed area, a targeted survey can be carried out to establish the current extent and distribution of the beds.
- If there is little or no existing seabed habitat data or it is out of date or of poor quality, you may need to undertake a geophysical survey to determine whether *M. modiolus* beds are present and the other seabed habitats in the survey area, including their distribution and extent. This information can be used to target habitat characterisation and monitoring surveys. If surveys are in close proximity to areas where *M. modiolus* beds have been recorded, benthic survey techniques that are more likely to record this habitat should be used.
- A sampling window between February to October is preferable, avoiding winter months.

- Relevant ecological parameters need to be selected. The key parameters to be assessed for *M. modiolus* beds in relation to EcIA are:
  - Extent and distribution of *M. modiolus* coverage with specific focus on dense aggregations that could be considered to represent 'biogenic reefs'
  - Integrity of the *M. modiolus* communities present (such as area, and whether dense aggregations or just a few individuals present)
  - Characterisation of associated epifaunal communities across the survey area
- Where geophysical survey identifies that *M. modiolus* beds are potentially present, a stratified grid-based design for ground truthing survey would generally be appropriate. If good quality geophysical data is available, a transect approach can be very effective for identifying habitat boundaries and transition zones for large sections of *M. modiolus* bed.
- Within-station sample replication would not generally be required for the habitat characterisation survey.
- For monitoring, replicate samples would usually be required in order to apply robust statistical techniques required to detect significant change in community characteristics.
- Sampling design options for monitoring include grid-based, simple random sampling and stratified random sampling. Stratification of sampling could be applied, for example, to areas of different *M. modiolus* density or different *M. modiolus* biotopes if more than one biotope present.

1.6. Survey and monitoring methods and analysis

A range of survey methods are appropriate for survey and monitoring of *M. modiolus* beds (section 5). Each provides information on different aspects of the habitat. The options include:

- Geophysical survey (such as side scan sonar and multibeam)
  - Provides information on the topography of the sea bed
  - can help characterise biogenic reef formations when data resolution and quality are sufficient
  - Ground truthing using other survey methods is required for more specific information about the extent and quality of the habitat
- Underwater image survey (such as towed video, still images, ROVs, AUVs, diver surveys):
  - Provides visual data on the habitat and conspicuous epibiota
  - Can be used to help determine habitat distribution and extent and presence and abundance of conspicuous epibiota
- Diver survey
  - Provides visual data on the habitat composition, quality and conspicuous epbiota
  - Can be used for targeted collection of biotic samples if required

Quality control measures for the field methods including species identification need to be clearly defined and implemented by field staff undertaking the survey work.

Not all methods will be required for a particular development or activity and proposed methods need to be defined on a project-specific basis. The JNCC Marine Monitoring Method Finder, a web-based information hub, has been developed to provide a single point of access to the numerous guidance documents and tools generated both within and outside the UK. It can be used in conjunction with this document to ensure a consistent approach to data collection and analysis.

2. Habitat introduction

2.1. Overview

The horse mussel *Modiolus modiolus* is a relatively common and widespread bivalve mollusc found around the UK. Under favourable conditions the species is known to form dense beds with very high densities of individuals (Holt *et al.*, 1998). These beds are typically at depths of 5–70 m in fully saline environments, often in moderately tide-swept areas. *M. modiolus b*eds are recorded from the southern parts of the Barents Sea and the White Sea to the southern North Sea and Irish Sea. The southern extent of the biogeographic range extends at least to the Bay of Biscay, but it is not known to form beds beyond the North Sea and the southern Irish Sea (OPSAR, 2009). In the UK and Ireland *M.* modiolus beds occur off northern and western coasts, the Irish Sea coasts and historic records in the North Sea (OSPAR, 2009).

M. *modiolus* aggregations can be present in a variety of situations. They can occur as relatively small, dense beds of epifaunal mussels carpeting steep rocky surfaces, as in some Scottish sea lochs but, more frequently are at least partly recessed into mixed or muddy sediments (Roberts *et al.*, 2011). In some sea lochs and open sea areas, extensive expanses of seabed are covered in scattered clumps of semi-recessed *M*. *modiolus* on muddy gravels. In a few places in the UK with areas of very strong currents, extensive areas of stony and gravelly sediment are bound together by more-or-less completely recessed *M*. *modiolus*, creating waves or mounds with steep faces up to one metre high and many metres long (Ramsay *et al.*, in draft). These areas of semi-recessed and recessed beds may in some cases extend over hundreds of hectares. In many cases the aggregations create multi-dimensional habitats and form 'biogenic reefs' which are considered to have high biodiversity value and are a protected habitat. The mussels have a stabilising effect on the seabed due to binding by their byssal threads. Substantial accumulations of dead shell often occur in and around the beds.

A workshop in 2014 concluded that, for the purposes of identifying *Modiolus modiolus* habitat, the definitions for *Modiolus modiolus* 'bed' and 'reef' should be considered the same entity (Morris, 2015). The term 'bed' is used in this document to refer to *Modiolus modiolus* aggregations / biogenic reef habitats.

M. modiolus is a long-lived species and individuals in beds are frequently 25 years old or more (up to 50 years has been recorded). Consequently, the beds are considered to be long-lived structures. Predation of juvenile *M. modiolus*, especially by crabs and starfish, is high until the mussels are about 3-6 years old, when it is considerably reduced (OSPAR, 2009). Once individuals reach 45-60 mm in length, they become relatively resistant to predation, as only the very largest crabs and starfish can open horse mussels over 50 mm in length (Anwar *et al.*, 1990, Holt *et al.*, 1998).

Recruitment of *M. modiolus* is sporadic and highly variable across temporal and spatial scales (including geographic location and depth) (Holt *et al.,* 1998). There can be poor recruitment across a number of years in some populations and, while some populations are probably self-sustaining, it is likely that a population that is reduced in extent or abundance will not recover for many years, if at all (UKBAP, 2008). Sexual maturity is considered to occur at about 35-40 mm (Anwar *et al.*, 1990) and coincides approximately with the size at which individuals become less prone to predation and can divert resources to reproduction (Brown & Seed, 1977).

Further information is provided in OSPAR (2009) and UKBAP (2008).

2.2. Sub-habitats

The Introductory Chapter (GN030-intro, section 3.2.4) provides information on the Joint Nature Conservation Committee (JNCC) and European Nature Information System (EUNIS) classification systems for marine habitats and biotopes. We recommend the JNCC website as a reference point to determine the latest guidance documentation for habitat and biotope assignment. The information provided below is based on the latest available guidance at the time of writing.

Within the EUNIS classification there are six *M. modiolus* biotopes listed under the broad scale habitat 'subtidal sediment' (EUNIS code A5). Table 1 shows this in the context of the overall EUNIS classification hierarchy with the *M modiolus* bed biotopes listed at EUNIS Level 5 as part of the biotope complex 'sublittoral mussel beds on sediment'. Four of the *M. modiolus* biotopes are bed forming (Table 2). The other two *M. modiolus* biotopes (Sparse *Modiolus modiolus*, dense *Cerianthus lloydii* and burrowing holothurians on sheltered circalittoral stones and mixed sediment (code A5.442); and, *Laminaria saccharina* with *Psammechinus miliaris* and/or *Modiolus modiolus* on variable salinity infralittoral sediment (code A5.532)) are not bed forming and are classified under a different main habitat type (Level 3) in the EUNIS classification; these two biotopes are not discusse4d further within this guidance and are not covered within the OSPAR (2009) background document for *M. modiolus* beds.

Table 1. The overall ENUIS habitat/biotope hierarchy for *Modiolus modiolus* at LEVEL 3 'Sublittoral biogenic reefs'

Level	EUNIS code	Habitat	Definition
Level 1	A	Marine Habitats	Marine Habitats
Level 2	A5	Broad Habitat	Subtidal sediment
Level 3	A5.6	Main Habitat	Sublittoral biogenic reefs
Level 4	A5.62	Biotope complex	Sublittoral mussel beds on sediment
Level 5	A5.621 – A5.624	Biotope	(see Table 2)

Table 2. The four EUNIS level 5 *Modiolus modiolus* bed biotopes

EUNIS Code	JNCC Code	Description
A5.621	SS.SBR.Smus.ModT	*M. modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
A5.622	SS.SBR.Smus.ModMx	*M. modiolus* beds on open coast circalittoral mixed sediment
A5.623	SS.SBR.Smus.ModHAs	*M. modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata

A5.624	SS.SBR.Smus.ModCvar	*M. modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata

The composition of the bed-forming biotopes is variable and is influenced by water depth, degree of water movement, substrate, and density of the horse mussels. These beds support a wide range of epifauna such as sponges, ascidians, soft corals, anemones, hydroids, bryozoans, tubeworms, brittlestars, urchins, starfish, barnacles, crabs and other decapods, whelks and other gastropods, scallops and fish, and there may be coralline algae and other red seaweeds in shallower areas. They can support a diverse infauna with niches for high numbers of crevice-living species, predators and scavengers (Rees *et al.*, 2008). The infauna often includes the purple heart urchin *Spatangus purpureus* and numerous bivalve species. Please refer to Figure 1 for example images of *M. modiolus* beds.

Figure 1. Plan view of *M. modiolus* bed, with *Alcyonium*, sponges and epifauna (left), image © NRW; view across *M. modiolus* bed, indicating topographic complexity and dense epibiota, image © Paul Kay

2.3. Extent/distribution in Wales

Many *M. modiolus* beds have not been monitored regularly and there is a lack of detailed up-to-date information relating to the distribution of *M. modiolus* beds over significant parts of their range (OSPAR, 2009). This is partly as result of the patchy distribution of this biogenic habitat and uncertainty as to whether records refer to the presence of *M. modiolus* individuals or bed structures.

In Wales a number of small separate beds have been recorded along the tide-swept coastline of north-west Anglesey (Rees, 2005). A more extensive bed off the north side of the Llŷn Peninsula in Caernarfon Bay has been particularly well studied (Lindenbaum *et al.*, 2008; Sanderson *et al.*, 2008; Rees *et al.*, 2008). There has been misinterpretation of grab sample records from further south in St George's Channel, where numerous *M. modiolus* spat have been recorded, but there is not yet any evidence of true bed structures in this locality (OSPAR, 2009). The distribution of *M. modiolus* beds in Wales is indicated in Figure 2.

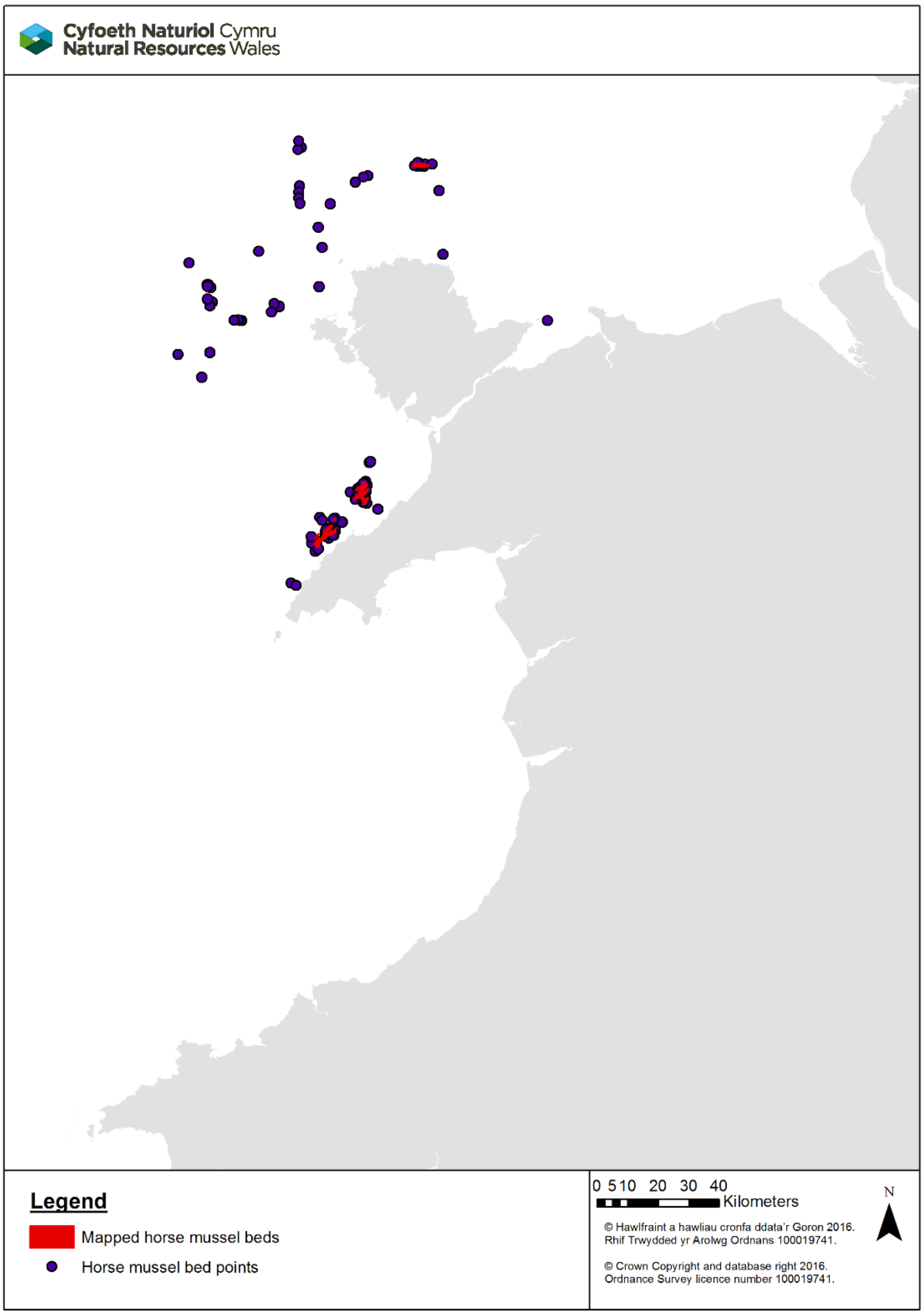

Figure 2. Location of *M. modiolus* beds in Wales

2.4. Conservation importance

The communities associated with *M. modiolus* beds are often extremely rich and diverse. The reefs provide species with shelter and act as important nursey and feeding grounds for diverse marine life including commercially important species of fish and shellfish such as whiting, cod, queen scallops and common whelks. (for example, Kent *et al.,* 2016).

Although *M. modiolus* individuals are relatively common, *M. modiolus* beds (with typically 30% *M. modiolus* cover or more) are more limited in their distribution. There are also several known examples where *M. modiolus* beds have been damaged or destroyed and have not, to date, recovered. *M. modiolus* beds support high levels of species diversity and provide valuable ecosystem services. Consequently, *M. modiolus* beds are designated as habitats of conservation concern and are protected under a range of environmental legislation.

The Introductory Chapter (GN030-intro, section 3.2.2) provides more general information on conservation policies and legislation, but key aspects relevant to *Modiolus modiolus* beds are highlighted below.

2.4.1. Habitats Directive

The Habitats Directive lists habitats and species of interest in Annex I and Annex II respectively. As *M. modiolus* beds can be considered as biogenic reefs, they are encompassed by the following Annex I habitat:

- Reef (code 1170)

Special Areas of Conservation (SACs) are protected sites designated under the Habitats Directive. In Wales, *M. modiolus* beds are part of the reef feature of the Pen Llŷn a'r Sarnau SAC.

2.4.2. Marine Strategy Framework Directive

Two of the 11 high level descriptors of Good Environmental Status (GES) in Annex I of the Directive (Defra 2014) relate directly to benthic habitats (D1 Biodiversity and D6 Seafloor integrity), with others relating to aspects of benthic ecology (for example, food webs and commercial fishing).

2.4.3. OSPAR list of threatened and/or declining species and habitats

Horse mussel *M. modiolus* beds is listed on the OSPAR List of Threatened and/or Declining Species and Habitats. A background document for this habitat is available from OSPAR (2009).

2.4.4. Environment (Wales) Act 2016 Section 7 list of habitats/species of principal importance (previously NERC S42 lists)

Horse mussel beds are listed as a Priority Habitat under Section 7 of the Act within the category of ‘Sublittoral sediment’.

2.4.5. Marine and Coastal Access Act 2009

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. *M. modiolus* beds can be MCZ features but, at present, the only MCZ currently designated in Wales is the Skomer MCZ which does not have *M. modiolus* beds within it.

The Act also established the requirement for marine licences for developments and activities in the marine environment.

2.4.6. Welsh Marine Protected Area Network

M. modiolus beds are considered within the Marine Protected Area network feature list for Wales (Carr *et al.*, 2016).

2.5. Key potential pressures

The potential pressures of marine developments and activities on *M. modiolus* beds and the species they support vary in relation to factors such as the nature of the development or activity, construction methods, mode of operation and scale of the project. In order to assess the significance of the effect of a given pressure on a specific receptor (such as a *Modiolus* reef), you will need to identify the factors and pressures associated with your proposed development or activity. You will need to consider these, along with the conservation value and sensitivity the habitat/species present and the magnitude of effect as part of the Ecological Impact Assessment (EcIA) (CIEEM 2018).

The main potential pressures include, but are not restricted to:

- **Salinity changes** e.g. Cooling water discharges, freshwater inputs or abstraction.
- **Temperature changes** e.g. Cooling water discharges.
- **Water flow (tidal current) changes; Wave exposure changes** e.g. Construction and operation of coastal/marine structures/developments (incl. tidal lagoons); extraction industry.
- **Nutrient (eutrophication) and organic enrichment; Presence of pollutants (and bioaccumulation)** e.g. Sewage effluent; Agricultural runoff; Marinas; Aquaculture; Spillage of chemicals during development construction/operation.
- **Changes to suspended solid levels (water clarity); Changes to siltation rates (smothering)** e.g. Dredging; Discharges to marine environment; Spoil disposal; Agricultural run-off; Extraction industry.
- **Loss of habitat in development footprint; Changes to, removal and disturbance of *M. modiolus* bed** e.g. Dredging; Trawling; Anchoring/mooring; Construction and operation of coastal/marine structures/developments; Trenching and pipe/cable laying; Dumping of spoil, Extraction industry.
- **Changes to sediment transport and erosion/accretion regime. Changes to habitat structure / sedimentology / geomorphology** e.g. Dredging; Construction and operation of coastal/marine structures/developments; Coastal defences (e.g. managed realignment); Extraction industry.
- **Introduction or spread of invasive non-native species (INNS)** e.g. Vessel activity; Discharges to marine environment; Marinas; Aquaculture; Spoil disposal; Construction and operation of coastal/marine structures/developments.
- **Removal of non-target species** e.g. Trawling.

- **Biological pressures** e.g. Other anthropogenic influences e.g. Waste tipping; Recreational pressures; electromagnetic changes.

2.6. Sensitivity (resistance/resilience to pressures)

For any species or habitat found in the 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 development or activity, it is important to understand their sensitivity to each of the specific associated pressures arising from the proposed works.

The Marine Life Information Network (MarLIN) provides sensitivity reviews for the four *M. modiolus* bed habitats listed in Table 2:

- *M. modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata
- *M. modiolus* beds on open coast circalittoral mixed sediment
- *M. modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata
- *M. modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata

The reviews indicate that *M. modiolus* beds have a high sensitivity to a number of physical pressures including smothering and siltation and some hydrological pressures.

It is important for you to read the further information and considerations related to MarLIN assessments in the Introductory Chapter (GN030-intro, section 3.2.6). It is also important to consider the sensitivities and traits of species found within *M. modiolus* beds. Species traits are discussed by Tillin & Tyler-Walters (2014) and incorporated into MarLIN and its Biological Traits Information Catalogue (BIOTIC) resource, with further information in the wider scientific literature.

3. Existing guidance and data

This section identifies information and guidance that may be useful in the context of survey and monitoring of *M. modiolus* beds. Whilst some of the guidance (such as for Common Standards Monitoring) is primarily for statutory monitoring work undertaken by ourselves and others, the documents and references may still provide useful contextual information and guidance on methods.

The JNCC has recently produced specific guidance for the monitoring of marine benthic habitats (Noble-James *et al.* 2017) which is a useful reference document for many aspects of monitoring.

3.1. Common Standards Monitoring

Common standards monitoring (CSM) was developed in the context of SSSIs and SACs to set and assess conservation objectives to help staff undertake site monitoring and assessment (JNCC 2004). A key use of this monitoring data is to satisfy the requirement to report on the status of protected habitats and species under Article 17 of the Habitats Directive (see 2.4.1.).

CSM is based on monitoring a set of mandatory attributes with the objective of assessing whether a site feature is in a favourable condition. As an example, the attributes that might need to be monitored for *M. modiolus* beds as a reef feature include:

- Extent
- Distribution
- Density and health
- Epibiota and infauna community structure

High level guidance for monitoring these attributes is provided in the relevant CSM Guidance (for example, Reefs (JNCC 2004a). The CSM documents provide broad guidance for feature-specific monitoring indicating the background, targets and monitoring techniques for feature attributes. In terms of survey methods, the CSM guidance primarily directs the reader to the Marine Monitoring Handbook (Davies *et al.* 2001). It should be noted that some of the technical details in the Marine Monitoring Handbook 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/monitoring requirements (not just for CSM).

3.2. Marine Strategy Framework Directive

Fariñas-Franco *et al*. (2014) provides guidance for the selection of appropriate community indicators for *M. modiolus* survey in relation to monitoring requirements for the Marine Strategy Framework Directive, and application of appropriate diver survey and remote operating methods and approaches for image analysis.

3.3. OSPAR Monitoring Guidance

Annex 2 of the OSPAR (2009) background document sets out a detailed proposed approach for monitoring of *M. modiolus* beds. The guidance covers the following four main survey approaches (further details on these methods are provided in Section 5):

- Sonar (Multibeam and Sidescan)
- Cameras (video and stills)
- Diver survey
- Grab and dredge sampling (as these sampling methods can damage habitat they should be avoided apart from under exceptional circumstances)

3.4. MESH guidance

The Mapping European Seabed Habitats (MESH) project produced 'Recommended operating guidelines' (ROGs) for marine habitat mapping survey methods and these are hosted in the MESH archive on the EMODnet website. A number of these ROGs are relevant to survey and monitoring of *M. modiolus* beds.

The MESH Atlantic Project updated the ROGs for LiDAR and side scan sonar and produced a new ROG for grab sampling. These documents will become available through the MESH archive but in the interim they need to be requested from one of the project partners who are listed on the project page of the keep.eu website.

Survey and monitoring work in relation to proposed developments and activities should have regard to the guidance provided in the ROGs. Specific ROGs are referenced where relevant in other sections of this guidance.

3.5. NMBAQC guidance

Operational guidelines for remote monitoring of epibiota using digital imagery and analysis of that data are presented within the following North-East Atlantic Marine Biological Analytical Quality Control (NMBAQC) guidance documents:

- Operational guidelines for remote monitoring of epibiota using digital imagery are presented in Hitchin *et al.* (2015). The guidance covers the approaches, available equipment and methods for a variety of camera systems, including towed camera sledges, drop down cameras and towed camera platforms, as well as remote-operated vehicles (ROVs) and the use of freshwater lens camera systems. It also provides information on quality control of imagery and analysis and a recommended approach for data review.
- Guidance on the analysis of remote underwater video footage and still images is provided in the epibiota remote monitoring interpretation guidelines (Turner *et al.*, 2016).

3.6. Data sources

Distribution data for subtidal habitats in Wales and the UK are available from a number of sources. Our Guidance Note GN006 Marine ecology datasets for marine developments and activities (Natural Resources Wales, 2019) identifies data sources for subtidal habitat maps. It also explains how you can access information about Marine Protected Areas in Wales including maps and supporting documentation on protected features, as well as data and maps on protected marine habitats and species in Welsh waters.

The most up to date data for *M. modiolus* beds in Wales is provided on the Welsh Government data portal 'Lle' where you can view and download the data. There are two map layers relevant to horse mussel beds that are provided as part of the marine habitat dataset for the Environment (Wales) Act Section 7 habitats and OSPAR protected habitats with both polygon and point data available.

4. Survey and monitoring design

The Guidance Note GN030 and Introductory Chapter GN030-intro explain when and why habitat characterisation and monitoring may be required in relation to proposed developments and activities and the over-arching principles for both of these. It is important to understand the differences between characterisation surveys and monitoring when designing project-specific survey programmes.

The information provided in the following sections presumes an existing knowledge of the presence of *Modiolus modiolus* beds in the area to be surveyed based on available ecological data and/or subtidal habitat surveys. If you have little or no seabed habitat data, refer to chapter GN030g on undertaking initial habitat characterisation surveys to determine the seabed habitats present and their distribution and extent.

4.1. Existing data

Where possible, a comprehensive desk-based review of all available data relevant to *M. modiolus* beds and other subtidal habitats within the area of interest should be conducted prior to designing any habitat characterisation surveys or monitoring programmes. Our Guidance Note GN006 (Natural Resources Wales, 2019) provides information on the marine ecology data sets we hold and routinely use and how you can access them. Further information relating to sourcing and using data is also provided in the Introductory Chapter GN030-intro (section 3.2.3) and Noble-James *et al*. (2017).

4.2. Selecting ecological parameters

The Introductory Chapter GN030-intro (sections 3.2.7. and 4.2.1) summarises the importance of selecting suitable ecological parameters for survey (known as ‘indicators’ for monitoring programmes) and the process to determine the effectiveness, appropriateness and validity of parameters.

The main ecological parameters that can be measured for *M. modiolus* beds include:

- Extent and distribution of *M. modiolus* coverage across the potential ZoI of a proposed development or activity, with specific focus on dense aggregations that could be considered to represent ‘biogenic reefs’.
- Integrity of *M. modiolus* communities. For example, are there healthy, large-scale, dense aggregations or just a few individuals?
- Characterisation of associated epifaunal communities across the survey area. This would include identifying the different taxa present within assemblages and their densities, and a subsequent calculation of summary statistics/diversity indices.

Extent and distribution are the most relevant parameters to be determined if beds occur within the ZoI but will be avoided by the proposed development or activity. However, if indirect impacts such as increased sedimentation and potential smothering are likely pressures from a proposed development or activity, greater attention would need to be given to assessing impacts on the reefs and associated species community.

4.3. Benthic habitat characterisation

4.3.1. Aims of benthic habitat characterisation surveys for *M. modiolus* beds

The aim of habitat characterisation survey is to collate data to describe the *M. modiolus* beds within the survey area, identify any other habitats and/or species of conservation importance and provide an up-to-date ecological appraisal to inform EcIA.

4.3.2. Design of benthic habitat characterisation surveys for *M. modiolus* beds

Development and activity specific information should inform the design of habitat characterisation surveys which will also be influenced by the scale of the proposed development or activity (see Introductory Chapter GN030-intro, section 3).

The range of available survey methods for habitat characterisation of *M. modiolus* beds is indicated in Section 5.1. The methods to be used should be determined on a project-by-project basis prior to survey.

Guidance for habitat characterisation survey design is provided in a range of sources including the Marine Monitoring Handbook (Davies 2001), Ware & Kenny (2011) and Noble-James *et al.* (2017).

If *M. modiolus* beds are known to occur in the proposed area, a targeted survey can be carried out to establish the current extent and distribution of the beds. In reality, however, it is more likely that a development or activity will be proposed for an area where there is little survey data. In these cases, a general benthic survey will be needed to record the habitats present and determine their extent and distribution which may require a geophysical survey. Information about geophysical survey is provided in this chapter but you should also refer to chapter GN030g of the guidance which addresses subtidal habitat characterisation surveys. If the proposed development or activity is for any of the areas north and west of Anglesey, or off the north Llŷn Peninsula, where *M.* modiolus beds have been previous recorded, benthic survey techniques that are more likely to record any *M. modiolus* beds present should be used (see Section 5).

4.3.2.1. Survey design options

The approach to a *M. modiolus* bed characterisation survey can vary depending on a range of factors including water depth, turbidity, size of survey area or potential habitat extent, survey objectives, budget, weather conditions and time constraints.

The approach usually taken is to use geophysical data (historic or from a bespoke survey) to identify potential areas of *M. modiolus* beds. This enables targeted ground-truthing (for example using underwater imagery) at specific locations of interest for more detailed environmental interpretation.

Geophysical surveys should be used to gather data on seafloor composition and help inform the overall assessment. Usually a side scan survey would be recommended, with data analysed as described in sections 5.1.2. and 5.2. This can be combined with multibeam survey to provide additional information (section 5.1.1.1), however, side scan is likely to be better than multibeam for identifying biogenic reef.

It is important to understand that geophysical survey alone cannot provide conclusive evidence of *M. modiolus* bed presence as its signature of reflectivity is similar to that of other features such as areas of coarse material (for example, large pebbles and small cobbles, or areas of shells (OSPAR, 2009; Ramsay *et al*., in draft). Additionally, where beds are potentially present, geophysical surveys cannot provide any data on the density or health of *M. modiolus*, or any data for associated epibenthic or infaunal communities. Consequently, biological ground-truthing (using, for example, underwater video survey) is always necessary to verify the outputs of geophysical surveys, with the geophysical outputs then likely to be extrapolated to a wider survey area.

Where the outputs of geophysical survey identify that *M. modiolus* beds are potentially present, a stratified grid-based design for ground truthing survey would generally be appropriate. This was the approach applied for surveys conducted at a site off north Anglesey, in areas considered to be likely *M. modiolus* beds based on acoustic survey outputs (Moore *et al*., 2016). Stations were assigned high and low priority: the high priority stations were selected to provide a broad coverage of the survey area and these were surveyed first. Additional low priority stations were then sampled, where possible, to achieve the highest level of coverage of the site in the boat time available. Targeted transects approximately 100 m apart, rather than specific drop stations, were surveyed at each station.

For large sections of *M. modiolus* bed the transect approach provides continuous data along a stretch of biogenic reef, and it is highly effective for identifying habitat boundaries and transition zones when encountered. Furthermore, using transects can reduce the need for multiple deployments and retrievals which, especially in deeper waters, can reduce survey time and therefore increase cost efficiency. This approach, however, relies on good quality geophysical data to enable transects to be targeted effectively.

4.3.2.2 Timing

See section 4.4.4.1.

4.3.2.3. Number of stations (sampling effort)

The main consideration for a *M. modiolus* bed habitat characterisation survey is to ensure that the number of stations to be sampled provides sufficient coverage of potential or known *M. modiolus* beds within the potential ZoI of a proposed development or activity. There needs to be a sufficient number of sample stations within the Zone of Impact (within the immediate footprint where the proposed works will occur and also outside of this but where effects may still arise).

4.3.2.4. Within-station replication

It is not expected that within-station replication would be required for a habitat characterisation survey of *M. modiolus*. Single transects, or single camera drops, at each station are sufficient as long as the image outputs are of sufficient quality for the habitat characterisation.

4.4. Monitoring

4.4.1. Aims of monitoring programmes for *M. modiolus* beds

The aims of the monitoring need to be clearly defined and will depend on the potential impacts of a proposed development or activity as identified through the EcIA process. The monitoring methodology, including experimental design, needs to provide sufficient information to satisfy the relevant environment assessment processes and any conditions set by the regulator.

Monitoring requires repeat sampling to detect change over time in one or more indicators (i.e. selected ecological parameters). In relation to regulatory development control, monitoring usually consists of pre-construction monitoring (the 'baseline'), monitoring during construction and operational monitoring (see Introductory Chapter GN030-intro section 4.1).

As noted in section 4.2 of the Introductory Chapter, it may be beneficial to make any development-related monitoring compatible with data from existing, ongoing monitoring programmes, such as those undertaken by NRW.

4.4.2. Defining hypotheses and trigger levels

Hypotheses to inform ecological monitoring are generally framed to detect change in a selected indicator over time, and to determine if any change observed is outside normal expectations. This hypothesis may often be in the form of a null hypothesis e.g. no change in the extent of the bed is hypothesised. In the context of regulatory development control and EcIA, key thresholds known as 'trigger levels' are generally set to help assess whether impacts are evident on a given indicator over the course of a monitoring programme, along with management action(s) to be implemented if trigger levels are exceeded. The Introductory Chapter GN030-intro (sections 4.2.2 and 4.2.3) provides further detail relating to hypotheses testing and considerations associated with the potential use of trigger levels.

4.4.3. Design of monitoring programmes for *M. modiolus* beds

As indicated above for habitat characterisation, geophysical surveys and appropriate analysis software can be used to obtain data for the topography and composition of the seafloor environment. This can help to identify areas of higher reflectivity associated with potential *M. modiolus* beds and sediments that have the potential for supporting bed formation in the future. These geophysical outputs require ground-truthing via field-based survey. At the monitoring stage, survey efforts will likely focus on more detailed environmental ground-truthing of any *M. modiolus* bed sites identified during the habitat characterisation survey.

If the development or activity results in a gradient of pressure from high to low from, for example, a point source discharge, then sampling would be needed along the anticipated gradient of the discharge outputs. Stations should therefore be located at set distances from the discharge point (this constitutes operational monitoring, see the Introductory Chapter GN030-intro, section 4.2).

4.4.3.1. Monitoring programme design options

Monitoring design will need to be determined on a case by case basis as it will be influenced by the hypotheses to be tested and the indicators to be measured. The Introductory Chapter GN030-intro (section 4) provides a range of considerations for the design of monitoring programmes.

The approach will be determined based on outputs of the survey approach applied for habitat characterisation. Design options include grid-based, simple random sampling and stratified random sampling (Noble-James *et al.* 2017). For a habitat type such as *M. modiolus* beds, the stratification option could be applied to sample, for example, areas of different *M. modiolus* densities (as identified from the habitat characterisation survey), or areas of different *M. modiolus* bed biotopes (where more than one biotope is present). Other design options are covered in detail in other guidance including the Marine Monitoring Handbook (Davies *et al.* 2001), Ware & Kenny (2011) and Noble-James *et al.* (2017).

Underwater imagery surveys for monitoring purposes can be based on either a transect-based sampling approach or a point-based approach at specific sampling stations. For monitoring *M. modiolus* beds in Strangford Lough, Roberts *et al*. (2011) adopted a grid-based approach using an ROV, and divers for point-based ground-truthing with diving teams photographing quadrats on the beds, supplemented by diver survey along 100 m transects. Whilst it is beneficial to acquire data using a range of methods, for development-specific habitat characterisation it is accepted that the use of multiple ground-truthing methods (for example use of both diver teams and DDV or ROV systems), is unlikely in most instances, due to budgetary, time and depth restrictions.

The extent and health of any *M. modiolus* beds targeted during monitoring should be confirmed via the field-based sampling. In addition, the presence of negative pressures (such as mechanical damage, pollution, substratum loss) should be recorded. Roberts *et al*. (2011) adopted the use of different grades for categorising health and condition of the *M. modiolus* communities during their monitoring program (Table 3) , and similar approaches have been used for monitoring geogenic and biogenic reefs for the offshore industry in the North Sea (for example, Irving (2009)). Using classifications for bed health allows an accurate determination of change over time, which can be considered as part of the overall monitoring programme outputs.

Table 3 Definitions used to assign conditions to live *M. modiolus* communities using historical and current surveys (Modified from Roberts *et al*., (2011))

M. modiolus condition	Grade
Continuous clumps (>5 Ind. Clump^{-1}) or > 1 clump m^{-2}, super abundant, abundant, dense, continuous, bed, thick, frequent	1
Discrete clumps (>3 Ind. Clump $^{-1}$) < 1 clump m^{-2}, frequent, occasional, patchy, damaged, clumps	2
Present (0-3 Ind. Clump $^{-1}$) < 1 clump m^{-2}, rare, present	3
Absent	4

4.4.3.2. Number of stations (sampling effort) and BACI design

To be able to detect change in the benthic environment due to a development or activity sufficient stations need to be incorporated into the monitoring programme design. You can find more information about this, the selection of control sites and Before-After-Control-Impact (BACI) monitoring designs in sections 4.2.4. and 4.2.5. of the Introductory Chapter GN030-intro.

4.4.3.3. Within-station replication

The amount of sample replication within each station is a key consideration in any monitoring programme. This needs to be determined on a case by case basis in relation to the specific monitoring requirements (see Introductory Chapter GN030-intro section 4.2.5.3).

In terms of monitoring of *M. modiolus* beds, within-station replication would be recommended for, for example, quadrat surveys assessing density of *M. modiolus*. Multiple images taken within a single station would also be considered as within-station replication. Requirements for replication within stations should be determined once the number of survey stations across the *M. modiolus* bed habitat has been determined.

4.4.4. Sampling timing, frequency and duration

4.4.4.1. Timing

It is possible to survey *M. modiolus* beds for most of the year although there are logistical issues with surveying in winter. *Modiolus* beds in shallower water may be influenced by winter storms and in these instances the winter months should be avoided for survey and monitoring, but all the known beds in Wales are at >20m depth and less likely to be influenced by storm conditions.

4.4.4.2. Frequency and duration

There is no set guidance on the frequency of sampling of *M. modiolus* beds for monitoring purposes. Relevant considerations when determining potential frequency and duration of monitoring are provided in the Introductory Chapter GN030-intro (section 4.3).

4.4.5. Supporting environment

It is important to consider other parameters relating to potential pressures arising from the proposed development or activity that may also require monitoring, in order to enable an assessment of their potential influence on *M. modiolus* beds over time. For example, monitoring patterns of sediment transport or the hydrodynamic regime (such as bed shear stress, current speed) within the survey area. These requirements should be determined through assessment of the likely impact pathways from a proposed development or activity and should be described in the monitoring plan.

5. Survey and monitoring methods and analysis

5.1. Field methods

A range of survey methods are appropriate for survey and monitoring of *M. modiolus* beds, depending on the local environmental conditions and the specific parameters or indicators being measured or assessed. The main options include:

- Geophysical surveys (side scan sonar and multibeam echosounder)
- Underwater image survey (such as towed video, still images) for acquiring data for sediment type (visual) and conspicuous biota
- Diver survey for acquiring data for sediment type (visual) and conspicuous biota, and collection of samples if required

Grabs, trawls and dredges are not recommended for sampling *M. modiolus* beds due to the damage these methods can cause to the biogenic reef habitat. These methods would only be approved in exceptional circumstances, where it can clearly be shown that such sampling is essential and that it is not possible to deploy less-damaging methods.

These methods are discussed in further detail below, with respect to the parameters that can be surveyed using these approaches. The types of methods that are appropriate will vary in relation to both the scale and nature of the proposed development/activity. Standard protocols are available for the most commonly used field methods and are indicated where applicable.

The JNCC Marine Monitoring Method Finder, a web-based information hub, has been developed to provide a single point of access to the numerous guidance documents and tools generated both within and outside the UK and can be used in conjunction with this document to assure a consistent approach to data collection and analysis.

5.1.1. *Modiolus modiolus* bed parameters

5.1.1.1. Extent & distribution of habitat

Geophysical survey

Geophysical surveys can provide an efficient and effective approach to assist with mapping the extent and distribution of *M. modiolus* bed habitats. Where *M. modiolus* occurs at sufficiently high densities (in terms of numbers, sizes and hence biomass), it modifies the acoustic response properties of the seabed and may create bedforms that can be seen on sonar records. A range of different types of sonar equipment have been successfully used to locate, survey and monitor *M. modiolus* beds, though they are not effective in all circumstances (Lindenbaum *et al*. 2008, OSPAR 2009).

Side scan sonar seems to be better at detecting biogenic reefs than multibeam echosounders (MBES), although supporting data may also be acquired using MBES. More detailed information on the use of acoustic data is included below where relevant. The most important consideration when using sonar equipment to survey *M. modiolus* beds is to ensure that there is adequate ground-truthing (for example using the methods indicated below) to confirm that the features observed do correspond to *M. modiolus* bed structures (OSPAR, 2009).

For a large development, NRW would generally expect both multibeam and side scan data to be collected. Ideally this should conform to International Hydrographic Organisation (IHO) standards (S44 and S57) and have regard for the guidance provided in the relevant MESH ROGs. Complete coverage of the development/activity area and any associated ZoI will be necessary. In addition to the standards recommended for this type of data acquisition, some specific guidelines for multibeam and side scan survey required for the survey of *M. modiolus* beds are provided below.

Guidance on geophysical survey and methods is provided in a number of sources including Ware & Kenny (2011), Saunders *et al*. (2011) and a number of MESH guidelines for seabed mapping including Hopkins 2007 and Henriques *et al*. 2013). See also chapter GN030g for general guidance on geophysical and ground-truthing surveys.

Side scan sonar

Side scan is particularly effective at discriminating features on the surface of the seafloor.

Analysis of the sonar data allows prominent seafloor features to be determined and helps to discriminate between different substrates, depending on the quality and resolution of the sonar data.

Harder areas (such as coarser substrates like boulders and bedrock reef) are areas of high reflectivity. They reflect more energy (high backscatter) and usually appear as a lighter signal on the image. Areas of low reflectivity (for example, softer substrates such as fine substrates) reflect less energy (low backscatter) and appear as a darker signal. Very dark areas normally mean the absence of backscattered sound, indicating a shadow behind objects. Further information related to the interpretation of backscatter is provided in Henriques *et al*. (2013).

Side scan sonars are characterised by a beam which is narrow in the horizontal plane and wide in the vertical plane. This creates a narrow acoustic sweep across the sea bed at right angles to the track of the towfish (the unit holding the sonar). Side scan sonars are available with frequencies ranging from about 5 kHz to 1 mHz. Lower frequencies provide a longer range with lower resolution whilst the higher frequencies have a higher resolution but a shorter range (e.g. 5 kHz system can have range of >50 km, while for 1 mHz system the range may be just 50 m), (Henriques *et al*. 2013).

For habitat mapping, side scan sonar should be deployed within a suite of complimentary survey methods including multibeam echo sounders to provide a georeferenced morphology over which high-resolution side scan mosaics can be draped (Henriques *et al*. 2013).

Multibeam echo sounders

Multibeam data provides a detailed bathymetric dataset for the survey area, allowing features such as undulations and sand ripples to be detected. Multibeam echo sounders (MBES) determine depth by accurately measuring the angles of emission, reception and two-way travel time for a pulse of sound energy from the emitting instrument (transducer) to the seabed and back.

A key benefit of MBES is its ability to simultaneously collect bathymetry and backscatter information in a single survey. The images obtained can be used to map the different acoustic characteristics of the seafloor, which in turn can be used to characterise seabed material when accompanied with ground-truthing from grab samples, seafloor photography and video, and/or following input to acoustic classification software. Guidance for the use of MBES is provided in the MESH swath bathymetry ROG (Hopkins 2007).

Multibeam data provides a detailed bathymetric dataset for the survey area, allowing undulations on the seafloor to be detected (OSPAR 2009). Identifying *M. modiolus* beds from other raised features, however, may not always be possible, although such beds often have different back-scatter characteristics which may be of more assistance (OSPAR 2009)(Figure 3).

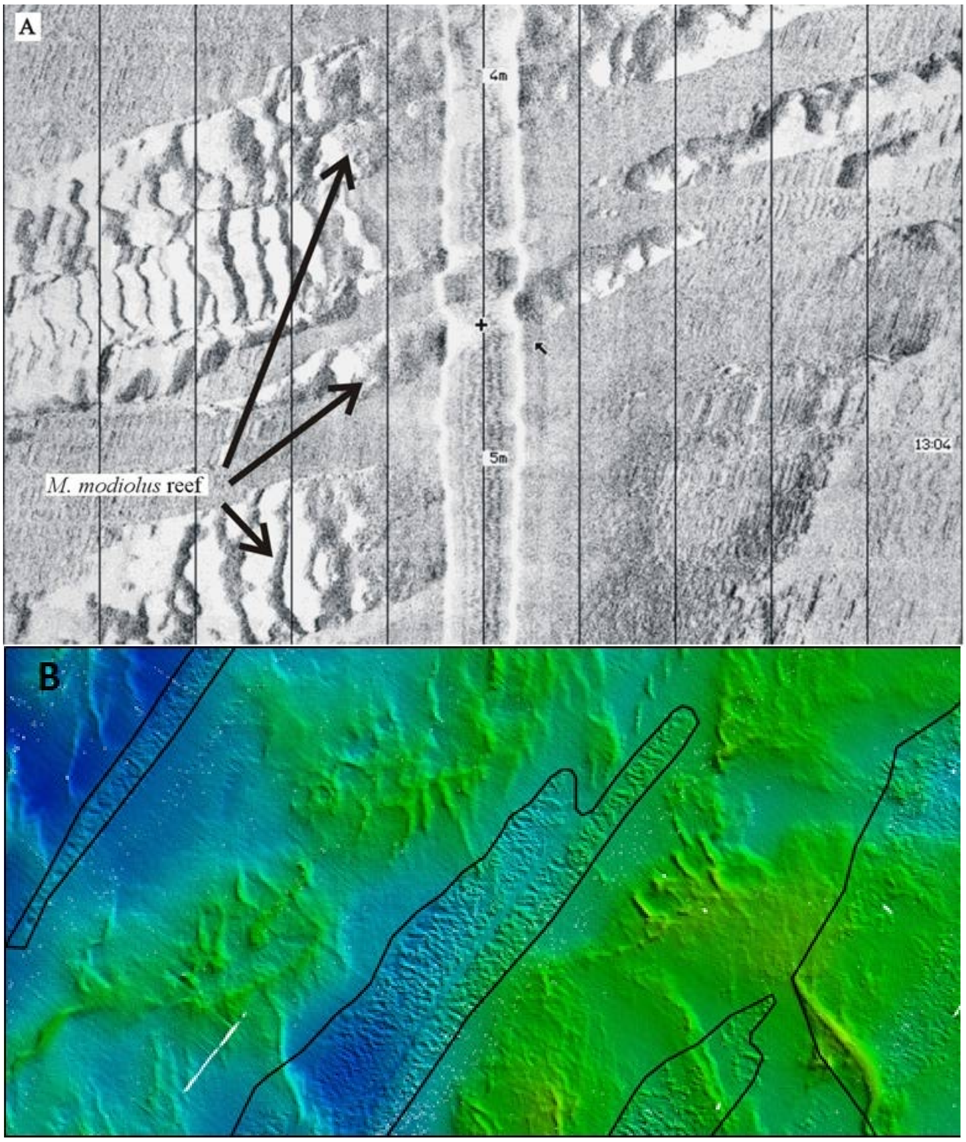

Figure 3: A. Characteristic mottled appearance of *M. modiolus* reef on side scan imagery. B. Characteristic mottled appearance of *M. modiolus* reef on multibeam echo sounder imagery. The reef delineation can be seen by the black borderline (from Ramsay *et al*. in draft). Image © NRW

Underwater imagery

Various image survey methods are available to collect video or stills imagery. The selection of any particular approach will depend on the aims of the habitat characterisation survey and the area and nature of the seabed to be surveyed. The main options include:

- Drop down video
- Towed video (with option for additional stills camera)
- Remote Operated Vehicle (ROV)
- Autonomous Underwater Vehicle (AUV) (currently unlikely to be cost effective but technological advances may make this a more feasible option in the future)

Towed image systems can physically impact *M. modiolus* reef habitat. Consideration should be given to using methods that have less physical contact with the seabed than more conventional towed systems, for example a flying array (Sheehan *et al.*, 2010).

Drop down video, towed video and remote operated vehicle (ROV) can allow visual characterisation of subtidal sediments including *M. modiolus* beds (Holt & Sanderson, 2001; Hitchin *et al.*, 2015). Imagery can include video and still photography and can be analysed *in situ* on the vessel or post-survey in a laboratory. Targeted image surveys can also be undertaken by divers, see section 5.1.1.2 – Diver survey.

Where *M. modiolus* forms dense beds, they are usually visible on the seabed and underwater video can be an effective technique for assessing the extent and distribution of the beds. The exceptions are where the amount of epifauna growing on them obscures the actual mussels but, even then, differences in the epifauna can often indicate where the mussel bed is located, and an experienced marine ecologist can often spot some of the shells that are partially open (OSPAR, 2009).

Detailed guidance on the approach for getting the best results with underwater video is available in the OSPAR (2009) background document for *M. modiolus* beds. In addition, a MESH ROG is available for 'Underwater Video and photographic imagery' (Coggan *et al*. 2007). Guidelines are also provided in Procedural Guideline 3-5 of the Marine Monitoring Handbook (Holt & Sanderson 2001), and more recent guidance is available in a North-East Atlantic Marine Biological Analytical Quality Control (NMBAQC) scheme Operational Guideline (Hitchin *et al.*, 2015).

Visual imaging will often allow enough epifaunal taxa to be recognised for a *M. modiolus* bed to be allocated to a particular EUNIS habitat classification type (although some variant assemblages may be present that do not fit any particular category). For example, bed types with an abundance of soft epifauna such as *Alcyonium digitatum* can be readily distinguished from those with more barnacles (OSPAR, 2009). For monitoring purposes, the image archive will show changes in some of the more prominent species, such as the numbers of brittlestars *Ophiothrix fragilis* overlying a bed or the abundances of large predators such as the starfish *Asterias rubens* (OSPAR, 2009).

Underwater imagery taken along transects (as opposed to point-based sampling) will provide additional habitat/biotope extent data and enable any small-scale habitats outside the target habitat (such as rock outcrops) to be identified.

Figure 4: Drop down video sledge ready for deployment (from Ramsay *et al*. in draft), image © NRW

With sled-mounted camera systems the optimum arrangement is to mount both a video camera and a separate still camera on the same frame, with the video facing obliquely forward and the still directly downward. The video footage provides an overview of the presence or continuity of the bed, plus an impression of the unevenness of the bed while the still camera produces a series of higher resolution images that allow accurate identification of the associated fauna (OSPAR, 2009). Video outputs can be of varying resolutions with a preference for high definition video cameras.

5.1.1.2. Mussel density, condition, epibiota community composition

Underwater imagery

Underwater imagery methods are described in section 5.1.1.1. In relation to community composition ecological parameters, underwater image techniques are only suitable for collection of data on conspicuous epibiota because the faunal communitiy within the bed is not visible. Esimates of % cover of conspicuous epibiota can be made from plan-view photography for images of known spatial area. Semi-quantitative estimates of abundance can also be made from underater imagery using the SACFOR scale of abundance: super-abundant (S), abundant (A), common (C), frequent (F), occasional (O), rare (R) and present (P) (JNCC 2010). The abundance ratings would be determined for each sampling location as opposed to each individual image.

Diver survey

Beds in relatively shallow water can be monitored by diving, which can allow more detailed assessment of the *M. modiolus* bed and the potential for identification of epifaunal species to lower taxonomic levels. Visual observation in the field can be supplemented by underwater photography.

Diver survey can be used to obtain quantitative data for epibiota and for the mussels themselves using quadrat-based survey approaches (OSPAR, 2009). Divers can undertake quantitative survey and counting of mussels *in situ* which is likely to be more accurate than image analysis on many beds where the *Modiolus* are obscured, either by other biota or sediment. However, the accuracy of diver counts may be influenced in part by the difficulty of standardising counting between observes (Sanderson *et al.*, 2008; OSPAR, 2009). Alternatively, divers can use video and still photography to obtain targeted images from the bed, including of quadrats, which can be analysed after the dive.

There is the option of using divers to collect samples. For example, all mussels can be collected by divers within quadrats (usually 0.25 x 0.25 m) to assess size-frequency distribution and to determine density (for example, Roberts *et al*., 2011). There is also the option for divers to collect cores from the *M. modiolus* beds if appropriate or use suction samplers to sample infauna for subsequent laboratory analysis. However, these approaches are destructive to the reef and are not generally recommended for development-related survey and monitoring. If infaunal samples are essential, their collection using divers is probably the least-impacting option. However, the potential impact of such sampling would need to be assessed and use of the method approved before any work is undertaken.

Diver survey is generally used:

- Where other means are not effective (such as remote underwater video)
- If finer detail needs to be recorded during a survey that would be difficult to determine from underwater video footage
- To ground-truth underwater imagery

Diver surveys may be particularly useful as they enable close inspection of *M. modiolus* and are the most likely method for identifying live mussels from recently deceased ones.

Guidelines for diver survey are provided in Procedural Guideline 3-3 of the Marine Monitoring Handbook (Holt & Sanderson 2001). Guidance on diver-operated cores is provided in Brazier (2001) and for diver-operated suction samplers in Rostron (2001).

Grabs, trawls and dredges

The crevice and infauna of *M. modiolus* beds are important as part of the overall ecosystem function of this habitat. In some circumstances physical sampling could be required to effectively monitor these components of the community, determine size-frequency distributions, and to record the presence of mussel spat living amongst the larger mussel clumps (OSPAR, 2009).

NRW does not recommend using grabs, trawls or dredges to sample *M. modiolus* beds due to the damage these methods could cause to the habitat. These methods would only be approved in exceptional circumstances, where it can clearly be shown that it is not possible to deploy less-damaging methods. If such methods were to be used, their potential impact on the reef would need to be fully assessed and the method approved before any work is undertaken. If infaunal samples are essential, their collection using divers is probably the least-impacting option but justification for sampling would need to be made and the impact of this assessed before any work is undertaken. To minimise potential disturbance to *M. modiolus* habitat, underwater imagery / observations are preferred.

5.1.2. Fieldwork Quality Control

All fieldwork should be carried out by experienced field scientists, with necessary health and safety provisions, and should observe the following points:

- There should be full sample tracking documentation and field notes for the sampling procedures
- Sample collection and handling during surveys must conform to the requirements of subsequent analytical analyses
- All processes should be witnessed and documented, with documentation retained after the surveys are completed

Across all methods it is important to obtain accurate, detailed records and to retain records/data for quality control/assurance procedures.

5.1.2.1 Geophysical survey

Acoustic data collection requires advanced survey instruments which require regular calibration to obtain high quality data and a sound technical knowledge of their operation. These surveys should therefore be undertaken by appropriately qualified and experienced personnel, preferably recognised by a professional institute (International Hydrographic Organization (IHO)) in line with relevant guidance. Amongst other things, attention needs to be given to accurately georeferencing the sounding footprint on the seafloor.

Side scan sonar

The height of the towfish above the seabed should be between 5 and 10% of the horizontal range setting. This usually allows a good level of seabed feature discrimination, including detection of some biogenic reef features. The overlap between tracks should be at least 50% and include appropriate cross tracks. Where complete seabed coverage is required for detailed feature or habitat mapping, ≥200% coverage is recommended.

Multibeam echo sounders

When collecting multibeam data, it’s important to maintain an appropriate overlap to ensure that 100% coverage is achieved without any data gaps or holes. Appropriate statistical analysis of cross line/main line intersections should be undertaken to assess the quality of the data.

5.1.2.2. Underwater imagery

The quality of underwater image data can be significantly limited by environmental conditions at the time of the survey as well as the deployment technique. For towed video systems the tow speed should be constant and suitable to allow seabed features to be observed; the towing vessel should head into the tide and speed over ground of the camera system should be ≈ 0.5 knot (Coggan *et al.*, 2007). If the camera system is towed too quickly the video is difficult to analyse and it reduces the information that can be extracted from the imagery. Also, the camera system can end up being lifted off the seabed so that no usable imagery is obtained. Particular care needs to be taken if deploying towed camera systems in areas of potentially strong tidal currents.

For underwater video to be effective there need to be adequate underwater visibility, and it cannot be used effectively in highly turbid areas (such as the Severn Estuary). In some instances, addition of a freshwater lens can improve the imagery obtained when underwater visibility is low (for example, Moore & Mercer, in prep).

Video and stills images can be rendered entirely useless for mapping purposes if they cannot be adequately georeferenced. Remote underwater video imagery equipment requires accurate timing and positions, which should be matched between on-screen data and actual times. Ultra-short Baseline (USBL) positioning should be employed where possible. Where this is not possible, camera position can be derived through calculation of layback from the ships's position (In waters shallower than 200m and providing currents are weak). Care must be taken to ensure that images are not obscured by equipment and to avoid disturbance to the seabed (to avoid turbidity and damage).

M. modiolus reef habitat is sensitive to physical impacts and care needs to be taken in the deployment of underwater imagery equipment to avoid disturbance of and damage to the habitat.

5.1.2.3. Diver survey

Care needs to be taken by the divers to reduce any disturbance to the horse mussel bed as a result of the survey work. All divers must be suitably qualified i.e. have an HSE Scuba qualification and be familiar with the aim, method and species of the survey.

5.1.2.4. Infaunal samples

In the unlikely event physical samples are collected, macrobenthic samples should be processed in line with the NMBAQC Scheme Processing Requirements Protocol (PRP) (Worsfold *et al.* 2010). Samples must be preserved and stored in sealed containers as soon as possible. Grab and core samples are generally preserved in buffered 4% formaldehyde solution in the field and are then sent to a benthic analysis laboratory. Other preservation methods may be considered for specialised purposes, such as use of ethanol for molecular studies.

5.2. Analytical methods

5.2.1. Geophysical data

Processing of acoustic data can be complex and will vary markedly depending on the method of collection. A variety of guidance is available (Henriques *et al.*, 2013; Plets *et al.*, 2013; IMCA, 2015) and should be followed where possible. All processing should meet International Hydrographic Organisation 1A standard (IHO, 2008).

The scale at which the data is examined appears to be important. If the multibeam bathymetry or side scan data is viewed at too small a scale, then biogenic features may be missed. It is therefore important to view the data at a range of scales; for example, scales of between 1:4,000 and 1:2,000 have previously been found to be appropriate for delineating biogenic *Modiolus modiolus* reefs from side scan data depending on their distinctiveness from the surrounding seabed. A scale of 1:2,000 allows a 300m square to be displayed comfortably on an average computer screen. It is advisable to look at the data at more than one scale, for example at a scale of both 1:4,000 and 1:2,000.

5.1.2.1. Side scan sonar

Raw side scan data are normally processed through proprietary software. Side scan sonar data can be processed in real-time to provide field surveyors with composite mosaics. This is suitable for initial quality control and preliminary on-board interpretation. However, like MBES-derived data, side scan sonars are susceptible to interferences from a number of sources (e.g. vessel noise), so the recorded raw data should be post-processed before attempting to classify seabed habitats.

Analysis of the sonar data enables determination of prominent seafloor features. Given the size and structure of aggregations of *M. modiolus* it is possible to identify aggregations and beds through the use of side scan sonar in a similar manner to identifying areas of coarse sediments or potential stony reef habitats. Typically, these are present within the side scan mosaic as areas of increased reflectivity with a mottled appearance, derived from small-scale topographic variations between individual mussels. It should be noted, however, that there are potential similarities in reflectivity of *M. modiolus* beds and with some other seafloor sediment features, and ground-truthing is necessary to confirm the geophysical findings (OSPAR 2009). Further information related to the interpretation of backscatter is provided in Henriques *et al*. (2013).

5.1.2.2. Multibeam echo sounders

The data collected from MBES systems are complex given that they can provide full bottom coverage and require a great deal of post-processing to apply positional, tidal and sound velocity corrections before meaningful interpretations can be made (see IMCA, 2015) Tidal information must be incorporated at the post-processing stage in order to correct all soundings to a standard water level. Additional data cleaning and checking may be required in regard to vessel navigation data.

Standard data processing for multibeam data can involve building a digital terrain model (DTM). This can be visualised in a variety of software packages and imported into a Geographic Information System (GIS), where it can be integrated with additional biological and geophysical datasets. Unlike data derived from single beam echo sounders, the DTM outputs are normally continuous (as long as 100 % coverage is achieved), meaning interpolation is not required.

Developments in multibeam echo sounder backscatter processing – specifically an integrated suite of processing algorithms called Geocoder – allow end-users to produce properly corrected backscatter mosaics and add more robust qualitative and quantitative discrimination of seabed materials to their seafloor characterisations. Fully corrected backscatter data increases confidence in interpretations of these data to assign seabed features/habitats. MBES data should be gridded at a suitable resolution so as to enable accurate bathymetric mapping. Where appropriate, shaded relief models may be created based upon the bathymetric outputs and the two can be overlain to provide additional information. The MBES outputs should be compared alongside the side scan sonar and biological ground-truthing which provide further detail.

Useful information regarding acoustic signals from *M. modiolus* bed habitats can be found in Lindenbaum *et al*. (2008) and Pearce *et al*. (2014). However, it is worth noting that the type of *M. modiolus* bed habitat that is the subject of the paper by Lindenbaum *et al.* (2008) is particularly distinct in terms of its morphology. *M. modiolus* bed habitats in other areas in Welsh waters (e.g. north and west of Anglesey) have a far less distinct acoustic signature.

5.2.2. Underwater imagery

All analysis of remote underwater video footage and still images should follow the NMBAQC / JNCC epibiota remote monitoring interpretation guidelines (Turner *et al.*, 2016) and be undertaken by a suitably qualified marine ecologist.

These protocols should be adapted within the specific context of surveying *M. modiolus* habitats: however, the broad principles required for the operation and analysis of drop down video footage should also be incorporated.

Taxa should, wherever possible, be identified to the lowest taxonomic level practicable. It is recognised that due to the limitations of seabed imagery not all taxa can be identified to species level and that identification also depends on the quality of the digital images and footage.

With digital stills it is possible to count and accurately identify a higher proportion of species than for video footage due to the higher quality images compared to a screen pause (even with HD video). Consequently, despite the value of obtaining video footage, digital stills can provide better and more reliable community composition and density data (for example, numbers of individuals of *M. modiolus* and other taxa per m^2) with non-countable taxa recorded as percentage cover. Further guidance is provided in Fariñas-Franco *et al*. (2014).

5.2.4. Analytical Quality Control

5.2.4.1. Geophysical data

It is important that side scan and multibeam data are analysed by someone experienced in interpretation of such data in relation to biological habitats and in particular biogenic reef habitats.

The data-processing routines of converting the raw sounding data to the final smooth sounding values are critical in producing quality bathymetric data from which biological habitats can be discriminated. Any methods used to derive final depths such as cleaning filters, sounding suppression/data decimation, binning parameters etc. should be applied sensitively, bearing in mind the importance of the sediment surface features.

Side scan sonar

Problems with detecting the sea bottom in a side scan sonar survey can be corrected during the post-processing stage. Selecting a suitable pixel size for production of the side scan mosaic must consider the resolution of the original acquisition frequency, the detail required, and size of the file that will be produced. It is important that adjacent survey lines are co-registered so that linear features such as sand wave crests join accurately across the survey lines.

Multibeam echo sounders

Tidal information must be incorporated at the post-processing stage in order for multibeam surveys to correct all soundings to a standard water level. Additional data cleaning and checking may be required with regards to vessel navigation and attitude (roll, pitch, and heave) data.

5.2.4.2. Underwater imagery

Underwater video and digital stills analysis should be undertaken by a suitably qualified marine ecologist. For small-scale surveys it is recommended that, wherever possible, all digital stills are subjected to quality control and review by a senior marine scientist. For larger projects this is not always practical, given time and cost restraints, in which case 10% of images should be subject to internal audit. If notable discrepancies are identified, it is recommended that all images are re-checked. If errors are identified that relate only to specific taxa, it may be feasible to just re-analyse the relevant images. Creation of a digital reference collection for each taxon is recommended for Analytical Quality Control (AQC) and to maintain consistency in identification.

5.3. Data analysis and interpretation

The Introductory Chapter GN030-intro (section 4.4) outlines approaches which are available for data analysis. The most suitable approach for each habitat should consider a variety of factors such as whether data are being analysed for a habitat characterisation or monitoring survey and the survey design. Further detail is provided in a wide range of published and grey literature such as Noble-James *et al*. (2017).

5.3.1. Habitat Characterisation and Monitoring

The key aim of the habitat characterisation data analysis is to provide the data outputs necessary to enable the subsequent interpretation required for EcIA and any associated assessments that are required such as Habitats Regulations Assessment and Water Framework assessment (see Guidance Note GN030, section 2.2).

The main targets of habitat characterisation for *M. modiolus* survey, and the range of statistical analyses to be applied, are in the ‘identifying patterns in multivariate community data’ grouping of statistical approaches (Noble-James *et al*. 2017). Analyses will involve calculating a range of appropriate metrics to characterise *M. modiolus* beds, which could include, for example, bed extent, *M. modiolus* density, proportion of live and dead individuals, epibiota abundance and taxon richness/diversity (Noble-James *et al*. 2017 and see Farinas-Franco et al 2014).

Monitoring data should be subject to in-depth 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 to achieve this and as a result those chosen are likely to vary markedly between projects. The proposed statistical tests to be used should be described at the monitoring programme design stage.

5.3.1.1. Habitat mapping

M. modiolus survey data may be most usefully presented as detailed survey maps, typically using GIS software packages.

These maps can indicate the distribution of different bed biotopes, and quantitative data including variation in, for example, density across the survey area, can be presented as bubble plots. Geophysical datasets may be imported in a variety of formats depending upon the software and data sources. Typically for ArcGIS, multibeam data is imported as an ASCII raster file, although georeferenced TIFF files (Geotiff) are also used. Colour scales may be applied to bathymetric data to assist with visual interpretation, and shaded relief (hill-shade) models can also be created and integrated to provide a combined colour-shaded relief or bathymetry figure. The Introductory Chapter provides further information relating to the types of classification systems that can be used to map benthic habitats and the inclusion of point sampling data within the mapping outputs.

6. References

Anwar NA, Richardson CA, Seed R. 1990. Age determination, growth rate and population structure of the horse mussel Modiolus modiolus. *Journal of the Marine Biological Association UK* 70, 441-457.

Brazier P. 2001. Procedural guideline No. 3-8: Quantitative sampling of subtidal sediment biotopes and species using diver-operated cores. In: Marine Monitoring Handbook, ed. by J. Davies, J. Baxter, M. Bradley, D. Connor, J. Khan, E. Murray, W. Sanderson, C. Turnbull and M. Vincent, 269-274. Joint Nature Conservation Committee.

Brown RA, Seed R. 1977. *Modiolus modiolus* (L.) - an autecological study. In: Keegan, B.F., O'Ceidigh P., Boaden, P.J.S. (eds). Biology of Benthic Organisms. Proceedings of the 11th European Symposium on Marine Biology, Pergamon Press, Oxford, Galway, Ireland, pp 93-100.

Carr H, Wright H, Cornthwaite A, Davies J. 2016. Assessing the contribution of Welsh MPAs towards and ecologically coherent MPA network in 2016. Joint Nature Conservation Committee.

CIEEM. 2018. Guidelines for Ecological Impact Assessment in the UK and Ireland: Terrestrial, Freshwater, Coastal and Marine. Chartered Institute of Ecology and Environmental Management, Winchester.

Coggan R, Mitchell A, White J, Golding N. 2007. MESH Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques.

Davies J. 2001. Chapter 2: Establishing monitoring programmes for marine features. In: Marine Monitoring Handbook, ed. by J. Davies, J. Baxter, M. Bradley, D. Connor, J. Khan, E. Murray, W. Sanderson, C. Turnbull and M. Vincent, 269-274. Joint Nature Conservation Committee.

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

Fariñas-Franco JM, Pearce B, Porter B, Harries D, Mair JM, Woolmer AS, Sanderson W G. 2014. Marine Strategy Framework Directive Indicators for Biogenic Reefs formed by *Modiolus modiolus*, *Mytilus edulis* and *Sabellaria spinulosa*. JNCC Report 523, ISSN 0963 8091.

Henriques V, Mendes B, Pinheiro LM, Gonçalves D, Long D. 2013. Recommended Operational Guidelines (ROG) for side scan sonars. MESH Atlantic.

Hitchin R, Turner JA, Verling E. 2015. Epibiota Remote Monitoring from Digital Imagery: Operational Guidelines.

Holt TJ, Rees EU, Hawkins SJ, Seed R. 1998. An overview of dynamic and sensitivity characteristics for conservation management of Marine SACs. Biogenic Reefs volume IX. Scottish Association for Marine Science (UK Marine SACs Project). pp 170.

Holt R, Sanderson B. 2001. Procedural Guideline No. 3-3. In situ survey of subtidal (epibiota) biotopes and species using diving techniques. In: Marine Monitoring Handbook, ed. by J. Davies, J. Baxter M. Bradley, D. Connor, J. Khan, E. Murray, W. Sanderson, C. Turnbull & M. Vincent. 241-251. Joint Nature Conservation Committee, Peterborough.

Hopkins A. 2007. MESH Recommended operating guidelines (ROG) for swath bathymetry.

IHO (2008) IHO standards for hydrographic surveys.

IMCA (2015) Guidelines for the use of multibeam echosounders for offshore surveys.

Irving R. 2009. The identification of the main characteristics of stony reef habitats under the Habitats Directive. JNCC Report No. 432, pp 44. JNCC, Peterborough, UK.

JNCC. 2004. Common Standards Monitoring Guidance for Generic Introduction for Marine Feature guidance. Version August 2004. Joint Nature Conservation Committee. ISSN 1743-8160 (online).

JNCC. 2004a. Common Standards Monitoring guidance for littoral rock and inshore sublittoral rock habitats. Version August 2004. Joint Nature Conservation Committee.

JNCC. 2010. SACFOR abundance scale used for both littoral and sublittoral taxa from 1990 onwards.

Kent FEA, Gray MJ, Last KS, Sanderson WG. 2016. Horse mussel reef ecosystem services: evidence for a whelk nursey habitat supporting a shellfishery. *International Journal of Biodiversity Science, Ecosystem Services & Management* 12(3), 172-180.

Lindenbaum C, Bennell J, Rees I, McClean D, Cook W, Wheeler A, Sanderson W. 2008. Small-scale variation within a *Modiolus modiolus* (Mollusca: Bivalvia) reef in the Irish Sea : I. seabed mapping and reef morphology. *Journal of the Marine Biological Association of the United Kingdom* 88 (1), 133-141.

Moore J, Jones J, Robinson K. 2016. Natural Resources Wales Rhiannon Modiolus 2015: video and still image analysis.

Morris E. 2015. Defining Annex I biogenic *Modiolus modiolus* reef habitat under the Habitats Directive: Report of an inter-agency workshop March 4th & 5th, 2014. JNCC Report No. 531. JNCC, Peterborough.

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.

Noble-James T, Jesus A, McBreen F. 2017. Monitoring guidance for marine benthic habitats. JNCC Report No. 598. JNCC, Peterborough.

OSPAR 2009. Background document for *Modiolus modiolus* beds. pp 30.

Pearce B, Fariñas-Franco JM, Wilson C, Pitts J, de Burgh A, Somerfield PJ. 2014. Repeated mapping of reefs constructed by *Sabellaria spinulosa* Leuckart 1849 at an offshore wind farm site. *Continental Shelf Research* 83, 3-13.

Plets R, Dix J, Bates R (2013) Marine Geophysics Data Acquisition, Processing and Interpretation: Guidance Notes.

Ramsay K, Walker P, Bayley D, Golding N, Robson L. (*In draft*). North West Anglesey Survey of Possible Horse Mussel Bed Areas. CCW Staff Science Report No: [in draft], 122pp, Natural Resources Wales, Bangor.

Rees EIS. 2005. Assessment of the status of horse mussel (*Modiolus modiolus*) beds in the Irish Sea off NW Anglesey. Department for Trade and Industry, Aberdeen (SEA6 Report.).

Rees EIS., Sanderson WG., Mackie ASY, Holt RHF. 2008. Small-scale variation within a *Modiolus modiolus* (Mollusca: Bivalvia) reef in the Irish Sea: III. Crevice, sediment infauna and epifauna from targeted cores. *Journal of the Marine Biological Association of the United Kingdom* 88, 151-156.

Roberts D, Allcock L, Franco JF, Gorman E, Maggs C, Mahon A, Smyth D, Strain E, Wilson C. 2011. *Modiolus* restoration research project: final report and recommendations. Report for Northern Ireland Environment Agency and Department of Agriculture and Rural Development.

Rostron DM. 2001. Procedural guideline No. 3-10: Sampling marine benthos using suction samplers. In: Marine Monitoring Handbook, ed. by J. Davies, J. Baxter, M. Bradley, D. Connor, J. Khan, E. Murray, W. Sanderson, C. Turnbull and M. Vincent, 293-306. Joint Nature Conservation Committee.

Sanderson WG, Holt RHF, Kay L, Ramsay K, Perrins J, McMath AJ, Rees EIS. 2008. Small-scale variation within a *Modiolus modiolus (*Mollusca: Bivalvia) reef in the Irish Sea: II. Epifauna recorded by divers and cameras. *Journal of the Marine Biological Association of the United Kingdom* 88, 143-149.

Saunders G, Bedford GS, Trendall JR, Sotheran I. 2011. Guidance on survey and monitoring in relation to marine renewables deployments in Scotland. Volume 5. Benthic Habitats. Unpublished draft report to Scottish Natural Heritage and Marine Scotland (Chapter 9).

Sheehan EV, Stevens TF, Attrill MJ. 2010. A Quantitative, Non-Destructive Methodology for Habitat Characterisation and Benthic Monitoring at Offshore Renewable Energy Developments. *PLoS ONE* 5(12), e14461.

Turner JA, Hitchin R, Verling E, Rein H van. 2016. Epibiota remote monitoring from digital imagery: Interpretation guidelines.

UKBAP (UK Biodiversity Action Plan). 2008. Priority Habitat Descriptions. Horse Mussel beds. (ed. Ant Maddock).

Ware SJ, Kenny AJ. 2011. Guidelines for the Conduct of Benthic Studies at Marine Aggregate Extraction Sites (2nd Edition). Marine Aggregate Levy Sustainability Fund, 82pp. ISBN: 978 0 907545 70 5.

Wildish DJ, Fader GBJ. 1998. Pelagic-benthic coupling in the Bay of Fundy. *Hydrobiologia* 375-376, 369-380.

Worsfold TM, Hall DJ, O'Reilly M. 2010. Guidelines for processing marine macrobenthic invertebrate samples: a Processing Requirements Protocol: Version 1.0, June 2010. Unicomarine Report NMBAQCMbPRP to the NMBAQC Committee 33pp.

Published by:
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