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Defining Annex I biogenic *Modiolus modiolus* reef habitat under the Habitats Directive: Report of an inter-agency workshop, March 4th & 5th, 2014

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Summary

The Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) is a European agreement that sets out a number of actions to be taken for nature conservation. It includes the requirement that Member States designate Special Areas of Conservation (SACs) to conserve certain Annex I habitats and/or Annex II species. The OSPAR Convention guides international cooperation on the protection of the marine environment of the North-East Atlantic. Annex V to the convention requires Contracting Parties to take necessary measures to protect and conserve the ecosystems and biodiversity of the maritime area and adopt programmes and measures to control human activities. Furthermore, the Biodiversity and Ecosystem Strategy sets out objectives to improve the status of and conserve threatened and/or declining species and habitats on the OSPAR List, and to achieve an ecologically coherent and well managed network of marine protected areas. Finally, the Natural Environment and Rural Communities Act 2006, Nature Conservation (Scotland) Act 2004, and the Wildlife and Natural Environment Act (Northern Ireland) 2011, all set out requirements to "have regard to" and "further the conservation of" biodiversity, in particular those habitats considered to be of principal importance.

Modiolus modiolus (horse mussel) beds are considered a type of Annex I biogenic reef habitat, an OSPAR listed habitat and a Habitat of Principal Importance across the UK. Habitats of Principal Importance (HPI) are generally the same as those listed on the old UK Biodiversity Action Plan, and will be known as 'UKBAP' habitats for the purposes of this report. Through their listing on these legislative instruments, *M. modiolus* beds were also considered as Habitats of Conservation Importance for the identification of Marine Conservation Zones under the Marine and Coastal Access Act 2009, and as Priority Marine Features for the identification of Nature Conservation MPAs under the Marine (Scotland) Act 2010. These reefs comprise either dense continuous beds, or scattered aggregations of this large mussel.

On March 4 and 5, 2014, the JNCC organised a workshop on "Defining *Modiolus modiolus* reef habitat" at Natural Resources Wales' (NRW) office, Bangor. This inter-agency *M. modiolus* workshop brought together staff with many years of experience within different disciplines in an attempt to provide more coherent standards for defining areas of *M. modiolus* reef habitat. Sixteen attendees took part, including representatives from national nature conservation agencies, universities and consultancies regularly working with *M. modiolus*. Over the two day workshop, a series of presentations and discussions took place to:

1. Clarify whether OSPAR and UKBAP *M. modiolus* 'beds' and Annex I 'reef' habitat definitions are the same for the purposes of the tool developed over the workshop.
2. Develop a clear thought process to aid agencies in identifying what is most likely to be *M. modiolus* reef habitat, and similarly most unlikely to be *M. modiolus* reef habitat.
3. Decide whether a 'reefiness' tool similar to the *Sabellaria spinulosa* (Gubbay 2007) or stony reef (Irving 2009) tools was required. If so, to discuss how best this tool would be developed, and whether condition or quality of reef should be incorporated into such a tool.
4. Provide guidance on the most appropriate survey methods for the identification (not monitoring) of Annex I *M. modiolus* reef habitat.

The 2014 inter-agency workshop concluded that the OSPAR and UKBAP *M. modiolus* 'beds' and Annex I 'reef' habitat definitions should be considered the same entity for the purposes of identifying *M. modiolus* reef habitat. The guidance provided in this report can thus be used

for identification of OSPAR and UKBAP *M.modiolus* reef habitat, due to the likelihood that any Annex I reef habitat identified will also fall within the scope of the current OSPAR and UKBAP habitat definitions.

Participants of the 2014 inter-agency workshop decided that in order to be classified as *M. modiolus* reef habitat, the following parameters were required:

- Live adult *M. modiolus* individuals are present;
- the associated reef biota/communities are distinct from the surrounding habitat; and
- the distinct region containing *M. modiolus* is greater than 25m^2 in extent.

Participants further concluded that there are two main types of *M. modiolus* reef around the UK; those on open coasts (such as off the North Llŷn Peninsula in Wales, and Noss Head in Scotland) and those forming in more sheltered but tidally swept areas (including Strangford Lough and Loch Alsh). As a result, the workshop decided a two stage approach to guidance was required. The first stage aims to ensure that the area meets basic reef criteria (criteria bulleted above). All stage one criteria must be met before moving onto the second stage, which ascertains whether the suspected biogenic reef is likely or unlikely to be *M. modiolus* reef habitat, with various indicators depending on the location. These criteria are summarised into coherent and user-friendly tools shown as separate text boxes. It is important to note that criteria differ slightly for open coast *M. modiolus* reef habitat and sheltered, or semi-enclosed, *M. modiolus* reef habitat.

The results aim to inform both staff of the Statutory Nature Conservation Bodies involved in Offshore Special Area of Conservation (SAC), Marine Conservation Zone (MCZ) and Nature Conservation Marine Protected Area (NC MPA) designation and management, and provide better guidance for consultancies undertaking technical reporting for Environmental Impact Assessments required during the consent and licensing processes in the marine environment.

Acknowledgements

JNCC acknowledge all the participants of the 2014 inter-agency *Modiolus* workshop. The dedication of conservation agency staff, contractors, researchers and freelancers, and the contributions, images and proof reading were all imperative to make a useful and user friendly guidance tool, and without them it would not have been possible. Specific thanks to Robert Cook (Heriot-Watt University) and Bernard Picton (Ulster Museum) for the use of their images in the report, and Ivor Rees for additional comments and images from SEA6 surveys. All attendees and contributors are listed in Appendix 2.

Contents

1 Background

The Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) is a European agreement that sets out a number of actions to be taken for nature conservation. It includes the requirement that Member States designate Special Areas of Conservation (SACs) to conserve certain Annex I habitats and/or Annex II species. The OSPAR Convention guides international cooperation on the protection of the marine environment of the North-East Atlantic. Annex V to the convention requires Contracting Parties to take necessary measures to protect and conserve the ecosystems and biodiversity of the maritime area and adopt programmes and measures to control human activities. Furthermore, the Biodiversity and Ecosystem Strategy sets out objectives to improve the status of and conserve threatened and/or declining species and habitats on the OSPAR List, and to achieve an ecologically coherent and well managed network of marine protected areas. Finally, the Natural Environment and Rural Communities Act 2006, Nature Conservation (Scotland) Act 2004, and the Wildlife and Natural Environment Act (Northern Ireland) 2011, all set out requirements to "have regard to" and "further the conservation of" biodiversity, in particular those habitats considered to be of principal importance.

A series of marine SACs have already been designated around the United Kingdom as its contribution to the European *Natura 2000* network. JNCC and the Country Nature Conservation Agencies have been working towards identifying SACs in offshore waters, as well as confirming existing areas, which includes collating data on any new or previously un-described Annex I sub-features (such as biogenic reef). One of the Annex I habitats listed for protection within SACs is 'Reefs'. These habitats can be either concretions of biogenic or geogenic origin that are defined as "hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions" (European Commission 2007).

"*Biogenic concretions*" can be defined as: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species (European Commission 2007). Under this definition *Modiolus modiolus* (horse mussel) beds are considered a type of Annex I biogenic reef. These reefs comprise either dense continuous beds, or scattered aggregations of this large mussel. The resulting reef mounds (composed of live mussels, mixed with shell debris and faecal matter) host a rich associated faunal community and are known to occur across UK waters.

Currently the definition of *M. modiolus* reef is taken from the OSPAR agreement 2008-07 (OSPAR 2008) for *M. modiolus* beds, the background document for which defines them as "patches extending over >10m^2 with >30% cover by mussels" (OSPAR Commission 2009). However, further areas are also considered as beds where "frequent smaller clumps of mussels so influence ecosystem functioning that for conservation and management purposes lower thresholds can be accepted". Additionally, "scattered populations of isolated full-grown individuals or of spat, at quite high densities, are not classified as 'beds'".

Within the field of marine conservation and management, a definition of *M. modiolus* beds and/or reef is required for a number of purposes including mapping of Annex I habitat, SAC site selection, and to consider the impacts of those human activities subject to Environmental Impact Assessments. As such, the need for a specific definition of Annex I *M. modiolus* reef is becoming more and more important. *M. modiolus* beds are also a Habitat of Principal Importance (HPI) in England, Wales and Scotland, and a Priority Habitat in

Northern Ireland[1] (formerly UKBAP habitats; Moore 2002; UK BAP 2008). However, the description given for the BAP habitat does not add much more detail to that given by the OSPAR definition.

There tend to be a number of issues with defining *M. modiolus* beds or 'reef'. In particular, defining areas >10m^2 can be difficult when *M. modiolus* are patchy in distribution, or appear to mostly consist of dead shell. The OSPAR background document states that "substantial accumulations of dead shell often occur in and around the long established beds". However, establishing the presence of live reef amongst dead shell can often be challenging, which makes it difficult to map the reef extent. In addition, areas where *M. modiolus* appear to be partially buried in the surrounding sediment can make it difficult to establish whether the area contains a large extent of reef, covered with a thin layer of sediment, or whether these are infrequent patches of *M. modiolus.* These problems are compounded in deeper waters offshore where in-situ survey by divers is impractical or impossible. In these areas the extent of *M. modiolus* beds often has to be defined using remote survey techniques, often comprising of a combination of acoustic surveys and images of the seabed from cameras on drop-down or towed platforms.

In May 2007, JNCC held a workshop on "Defining and managing *Sabellaria spinulosa* reefs" (Gubbay 2007) to improve the definition of Annex I Reef for *Sabellaria spinulosa* in UK waters. A similar workshop was held in March 2008 on "The identification of the main characteristics of stony reef" (Irving 2009).

Both these workshops successfully determined key criteria for the definition of these types of Annex I reef habitat that have been extremely useful for practitioners aiming to classify and map this habitat. A similar approach was required for *Modiolus modiolus* reef. As such, JNCC and NRW organised an inter-agency workshop on *M. modiolus* reefs (hereafter referred to as the 2014 inter-agency workshop) with representatives from a range of organisations, with the aim of combining and documenting their expertise in *M. modiolus* reef identification and management to improve the consistency and clarity of future work.

The following specific questions were raised by practitioners to guide the production of an 'identification tool' over the course of the workshop:

- Are 'mussel beds' the same as 'mussel reef'?
- What extent of mussel beds should be considered an Annex I reef habitat?
- What percentage cover and patchiness of an area would be considered Annex I reef habitat?
- What degree of 'topographical distinctness' or elevation should be considered Annex I reef habitat?
- What is the habitat's typical depth range?
- What environmental conditions are necessary for the habitat?
- What range of forms might, or should, be considered within the Annex I definition?
- Should Annex I reef habitat include partially buried, sand inundated or dead shell examples?
- Is the age or density of *M. modiolus*, or proportion of live/dead shells, imperative to defining Annex I biogenic *M. modiolus* reef habitat?
- Does the ecosystem functioning of the *M. modiolus* reef need to be considered when identifying the Annex 1 reef habitat
- Does an Annex I reef have to have a specific community structure or diversity?

[1] These habitats are based on the former UK BAP habitats, and are defined using the UKBAP description documents. As such, for the purposes of this report, HPIs and Priority Habitats will be referred to as BAP habitats, but it is important to note that the UK BAP has been superseded by the UK Post-2010 Biodiversity Framework (JNCC & Defra 2012).

- SAC selection – can we protect a habitat which is not easily defined or identifiable?
- Are 'proxies' necessary and acceptable.

1.1 Aims of workshop and reporting

Prior to the workshop the agencies agreed the overall rationale behind the 2014 inter-agency *M. modiolus* reef habitat workshop was to develop a "more precise definition of what should be assigned as *M. modiolus* reef", to help define key methods, associated species and geographical variation, and to develop a scoring system to define presence of different types of reef.

The main aims of the 2014 inter-agency workshop "Defining Annex I biogenic *Modiolus modiolus* reef habitat under the Habitats Directive" were as follows:

1. To clarify whether OSPAR and UKBAP *M. modiolus* 'beds' and Annex I 'reef' habitat definitions are the same for the purposes of the workshop tool.
2. To develop a clear thought process to aid practitioners in differentiating what is likely to be Annex I biogenic *M. modiolus* reef habitat, and what is unlikely to be Annex I biogenic *M. modiolus* reef habitat.
3. To provide guidance on the most appropriate survey methods for the identification (not monitoring) of Annex I biogenic *Modiolus* reef.
4. To decide whether a 'reefiness' tool, similar to the *Sabellaria spinulosa* (Gubbay 2007) or stony reef (Irving 2009) tools, is required. If so, how would this best be developed, and should condition or quality of reef, be incorporated into such a tool?

This report intends to: present existing definitions of *M. modiolus* 'bed' and 'reef'; describe the fundamental ecology and variation in *M. modiolus* reef and current problems with confident identification of Annex I biogenic *M. modiolus* reef; summarise workshop presentations (more detailed notes for which are provided in Annex I); and utilise discussion points to conclude with a definitive guide on how to confidently assign survey records to the Annex I biogenic *M. modiolus* reef habitat under the EC Habitats Directive.

2 Definition of *Modiolus modiolus* reefs

The horse mussel, *Modiolus modiolus*, was first described by Linné in 1758, and since then has been well documented as forming ‘reefs’ and ‘beds' (Roberts 1979; Holt *et al* 1998; UK BAP 1999; Moore 2002; European Commission 2007; UK Bap 2008; Baxter *et al* 2011). However, there is no common consensus on the definition of ‘reef’ or ‘bed’. Given the importance attributed to *M. modiolus* reef/bed, both as a qualifying habitat for Marine Protected Area (MPA) designation, and more widely as a habitat of conservation importance, a common approach to the definition of the habitat is needed.

Relevant selections of each current nature conservation initiative have been provided in Box 2.1 (Annex I and OSPAR) and Box 2.2 (BAP, Habitats of Principal Importance and relevant biotopes). This biogenic habitat was also identified as a habitat Feature of Conservation Importance (FOCI) for the Marine Conservation Zone Project in English inshore, and English, Welsh and Northern Irish offshore waters. Furthermore, it is considered a Priority Marine Feature to target marine conservation action in Scotland’s seas (Scottish Government 2013).

The aim of the 2014 inter-agency workshop was to develop clear guidance on how to identify, specifically, Annex I biogenic *M. modiolus* reef habitat, under the EC Habitats Directive. This current section aims to present parts of existing definitions of *M. modiolus* ‘bed’ and ‘reef’ (Boxes 2.1 & 2.2), some background information on the fundamental ecology of *M. modiolus* ‘bed’ and ‘reef’ (Section 2.1), geographic variation (Section 2.2) and other characteristics that make it challenging to determine the presence of *M. modiolus* biogenic reef. Later sections then focus on the workshop (Section 3) and resulting additional guidance in Section 4.

Box 2.1: Selected Annex I and OSPAR guidance on defining *Modiolus modiolus* 'reef' and 'bed'.

EC HABITATS DIRECTIVE: Annex I Feature of Biogenic Reef: *Modiolus modiolus*

*"Reefs can be either **biogenic concretions** or of geogenic origin.They are hard compact substrata on solid and soft bottoms, which arise from the sea floor in the sublittoral and littoral zone. Reefs may support a zonation of benthic communities of algae and animal species as well as concretions and corallogenic concretions".....*

***'"Biogenic concretions'** are defined as: concretions, encrustations, corallogenic concretions and bivalve mussel beds originating from dead or living animals, i.e. biogenic hard bottoms which supply habitats for epibiotic species."* (European Commission 2007).

Biogenic Reef has been further defined by Holt *et al* (1998) as *"structures which are created by accumulations of organisms, usually rising from the seabed, or at least clearly forming a substantial, discrete community or habitat which is very different from the surrounding seabed. The structure of the reef may be composed almost entirely of the reef building organism and its tubes or shells, or it may to some degree be composed of sediments, stones and shells bound together by the organisms"….*

"Those beds of the horse mussel Modiolus modiolus *that build up bioherms are likely to be persistent features in the long term. Evidence for this comes mainly from the scale of build up, the ages of the older animals (30-40+ years), the wide range of individual's size usually present and anecdotal history.*"

(Holt *et al* 1998; European Commission 2007)

OSPAR CONVENTION: In 2004, *M. modiolus* beds were listed as a threatened and/or declining habitat (OSPAR, 2008).

"The horse mussel Modiolus modiolus *forms dense beds, at depths up to 70m (but may extend onto the lower shore), mostly in fully saline conditions and often in tide-swept areas"….*

*"*M. modiolus *forms 'beds' (biogenic reefs) on the seabed where dense populations of these large bivalves occur* (Holt *et al* 1998)*"….*

"Patches extending over >10m^2 with >30% cover by mussels should definitely be classified as 'bed'. However, mosaics also occur where frequent smaller clumps of mussels so influence ecosystem functioning that for conservation and management purposes lower thresholds can be accepted. Scattered populations of isolated full-grown individuals or of spat at quite high densities are not classified here as 'beds'…."

"In addition to its listing by OSPAR, this habitat is the subject of several local, national and regional listings, including the Habitats Directive (as part of 'Reefs') and the UK Biodiversity Action Plan. Such listings serve to highlight the conservation needs of the habitat, but successful protection depends on specific actions that follow. In the UK M. modiolus *beds are identified as features for protection in SACs (Special Areas of Conservation) off Scotland, Wales and Northern Ireland".*

(OSPAR Commission 2009)

Box 2.2: UK BAP, Habitats of Principal Importance/Priority Habitat definitions of *Modiolus modiolus* 'bed' and 'reef' and associated biotopes.

UK HABITAT OF PRINCIPAL IMPORTANCE (previously BIODIVERSITY ACTION PLAN HABITAT): Horse Mussel Beds.

(An English, Welsh & Scottish Habitat of Principal Importance and a NI Priority Habitat)

UK: "*The horse mussel (*Modiolus modiolus) *forms dense beds at depths of 5-70m in fully saline, often moderately tide-swept areas off northern and western parts of the British Isles. Although it is a widespread and common species, true beds forming a distinctive biotope are much more limited and are not known south of the Humber and Severn estuaries.* M. modiolus *can occur as relatively small, dense beds of epifaunal mussels carpeting steep rocky surfaces, as in some Scottish sea lochs, but is more frequently recessed at least partly into mixed or muddy sediments in a variety of tidal regimes*"....

"*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, beds are more or less continuous and may be raised up to several metres above the surrounding seabed by an accumulation of shell, faeces, pseudofaeces and sand. In some 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. These areas of semi-recessed and recessed beds may in some cases extend over hundreds of hectares, and in many cases may be considered as `biogenic reefs`, though they are all referred to here as beds*"....

"The byssus threads secreted by M. modiolus *have an important stabilising effect on the seabed, binding together living* M. modiolus*, dead shell, and sediments".....*

"The composition of the biotopes is variable, and is influenced by the depth, degree of water movement, substrate, and density of M. modiolus*."* (UK BAP 2008).

Scotland: *"Horse mussels can form dense raised beds and occur down to around 100m depth. They significantly modify the underlying habitat and provide substratum and refuge for a wide variety of species, including brittlestars, featherstars, crabs, whelks, sponges, sea firs, sea mats and sea squirts and are important settling grounds for commercially important bivalve molluscs such as scallops. Scotland holds around 85% of the known horse mussel beds in the UK and are found in sea loch and embayments from Shetland and Orkney and down the west coast and Outer Hebrides."* This document then goes on to describe the four JNCC/MNCR Biotopes which are accepted variations of *M. modiolus* reef. (Baxter *et al* 2011).

(UK BAP 1999; Moore 2002; UK BAP 2008; Baxter *et al* 2011)

RELEVANT BIOTOPES:

Although *M. modiolus* occurs in many biotopes, currently OSPAR, Annex I and BAP only list the following biotopes for *M. modiolus* reef/bed:

JNCC/MNCR National Marine Habitat Classification for UK & Ireland:

SS.SBR.SMus.ModT, *Modiolus modiolus* beds with hydroids and red seaweeds on tide-swept circalittoral mixed substrata;
SS.SBR.SMus.ModMx, *Modiolus modiolus* beds on open coast circalittoral mixed sediment;
SS.SBR.SMus.ModHAs *Modiolus modiolus* beds with fine hydroids and large solitary ascidians on very sheltered circalittoral mixed substrata;
SS.SBR.SMus.ModCvar - *Modiolus modiolus* beds with *Chlamys varia*, sponges, hydroids and bryozoans on slightly tide-swept very sheltered circalittoral mixed substrata.

EUNIS Codes: A5.621, A5.622, A5.623 and A5.624 (Connor *et al* 2004; EUNIS 2012).

2.1 Fundamental ecology of *Modiolus modiolus* beds and reefs

The horse mussel, *M. modiolus*, rarely grows as a 'bioisolate' (a single individual with attached epifauna). Instead, *M. modiolus* spat preferentially settle in areas of existing adults, where survival is higher amongst the byssal threads of their aggregated adult relatives. Frequently adults are long lived to over 25 years or more, but do not become sexually mature until three-six years old (Holt *et al* 1998). Naturally, once established, this leads to a colonial behaviour (Roberts 1979), where colonies start as small clumps but grow into extensive 'bioherms' in the right conditions (Ivor Rees, *Pers. Comm.* 2014), often forming waves or continuous beds.

Once settled, *M. modiolus* forms reef by aggregating into clumps bound together by their secretion of byssal threads and in doing so stabilise the often sedimentary seabed (OSPAR Commission 2009). This complex network of byssal threads has an important ecosystem function in binding the sediments together; *M. modiolus* has been found to produce more byssal threads per shell, and adhere to more and larger particle sizes than its closest local relative *Mytilus edulis* (Shand 1987). These spatially complex aggregations host a plethora of infauna, crevice fauna and epifauna. *M. modiolus* reef ridges on the North Llŷn Peninsula, North Wales, were found to have crevice and infauna almost three times more abundant than surrounding troughs (Rees *et al* 2008) and overall a very distinct faunal community compared to the rest of the Irish Sea sediments. The associated fauna is not the same in every bed, but instead varies geographically and with the physical characteristics of the bed (Section 2.3).

Figure 2.1: North Llŷn Peninsula Annex I biogenic *M. modiolus* reef habitat with high density of live individuals and a diverse associated epifauna of anemones (Sagartia sp.), *Alcyonium digitatum*, brittlestars, hydroids and several encrusting species. (Image © NRW)

Also important in the formation of *M. modiolus* reef is the deposition of pseudofaeces. Faecal pellets enrich the reef itself with organic matter to feed crevice fauna and infauna (Rees *et al* 2008), and feed into the plankton and enrich the local water column. These filter feeding biogenic reefs also capture and recycle chlorophyll a from the plankton (Navarro & Thompson 1997) and therefore have a potentially important role in wider ecosystem functioning and even carbon sequestration.

It must also be noted that *M. modiolus* reefs are distributed towards the north of the British Isles, with the most southerly known bed being off North Wales. With climate change and increasing sea temperature, these reef formations may be pushed north (Hiscock *et al* 2004). Furthermore, Gormley *et al* (2013) undertook a modelling study of the possible effect of climate change on *M. modiolus* reef at the current rate of temperature increase, and predicted 100% loss of 'most suitable' UK habitat by the year 2080 (based on a 3.12^{o}C predicted rise in ocean temperature).

Holt *et al* (1998) recognised that "*Modiolus modiolus* reef can take two main physical forms:
1) semi infaunal reefs, which grade in density and thickness from continuous dense, raised reefs to scattered clumps; and
2) an infaunal gravel embedded reef community which in Britain can form wave like mounds up to one metre high". The report went on to further define the differences between these two forms. The term 'bioherm' is a useful word used to describe and visualise *M. modiolus* reef or bed, as it implies some sort of aggregation of the organisms bound together by some mechanism and thus structuring the seabed. The amount of elevation above surrounding areas can be very slight or it can be massive" (Ivor Rees, *pers. comm.* 2014). The 2014 inter-agency workshop further refined these descriptions in light of recent evidence, presented in Annex I (separate document) and Sections 3 and 4 of the current report. Both Holt *et al* (1998) and the OSPAR Commission (2009), provide further detailed information regarding the general ecology and importance of *M. modiolus* reef.

It should be noted that there are two other *M. modiolus* species that overlap in geographic range with *M. modiolus*: the more southerly species *Modiolus adriaticus* and *Modiolus barbatus*. Both of these species are both less inclined to aggregate than *Modiolus modiolus*. *Modiolus adriaticus* can easily be misidentified as *M. modiolus*, and is often found singly and surrounded by coarse sand particles so that it appears to be inside a ball like nest, rather than forming distinctive clumps or bioherms (Ivor Rees, *pers. comm.* 2014).

2.2 Geographic variation

Prior to the introduction of the Marine Nature Conservation Review (MNCR, Hiscock *et al* 1998) and the Marine Habitat Classification for Britain and Ireland (Connor *et al* 2004), Holt *et al* (1998) described different types of *M. modiolus* biogenic reef, and biotopes that would not be described as reef, together with example beds from different geographical areas. The OSPAR Commission (2009) background document for *M. modiolus* beds also refined further geographical variations in *M. modiolus* beds across northern Europe. The 2014 inter-agency workshop aimed to refine this list into more definitive guidance on how to identify Annex I biogenic *M. modiolus* reef habitat. In order to achieve this aim, all UK nature conservation agencies were asked to provide examples of what is, and is not, currently considered *M. modiolus* reef in their associated seas prior to the workshop, with the rationale for its designation in existing MPAs where appropriate.

As introduced in Section 2.1, *M. modiolus* can take several forms (Tables 2.1–2.4), from individuals to sparse low lying clumps, large raised clumps, and 'bioherms'. It is evident from these tables that particular types of reef formation are not unique to any specific geographic area. The form a reef takes appears to be more related to the prevailing physical factors affecting its development; primarily its exposure to wave and tide action.

Shallow, sheltered, tide-swept areas such as sea lochs and the Sullom Voe often seem to have clumping reefs (Table 2.3). Open coast, deeper reefs, including the coastal Irish Sea, may form extensive beds or 'bioherms' (Table 2.4). Very tidally swept, open coast reefs, including those north of the Isle of Man and off Arklow (Republic of Ireland), >12nm off North Anglesey (Table 2.3) and Noss Head (Scotland, Table 2.4) seem to have less abundant large epifauna (such as *Alcyonium digitatum)* but instead support a diverse encrusting epifauna and infauna assemblage. It was the uncertainty of form, particularly around records showing sparse clumping and very tidally swept reefs dominated by dead shell (Table 2.2), which drove the discussions of the 2014 inter-agency workshop on "Defining Annex I biogenic *M. modiolus* reef under the Habitats Directive", to determine if user friendly guidance could be provided to assist in the positive identification of these potential *M. Modiolus* reefs as Annex I biogenic reef habitats. Section 4 presents the final results.

Table 2.1: Examples of images of *Modiolus modiolus* currently NOT considered Annex I biogenic reef habitat.

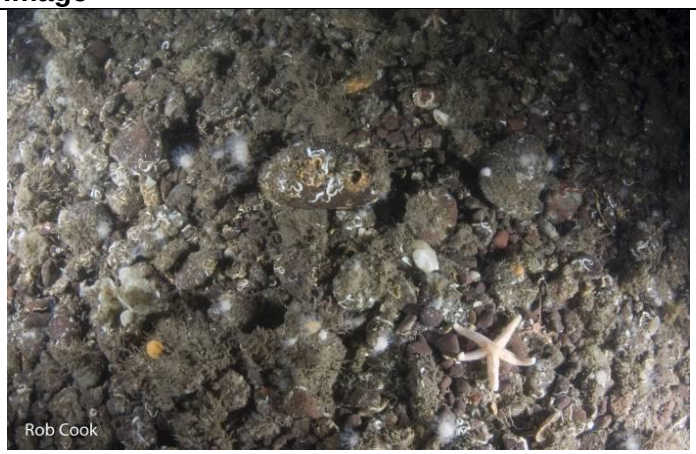
Reef Form	Image	Location
Rare subtidal 'bioisolate' of single, non reef forming *M. modiolus*.	 © Rob Cook	St Abbs, England
Suspected area of reef comprising dead shell and occasional live *M. modiolus*. Unlikely to be Annex I biogenic *M. modiolus* reef habitat.	 © JNCC/Cefas	Mid St George's Channel, Irish Sea
Small isolated clumps of *M. modiolus*, starting to develop some associated community, but not forming reef over a large area.	 © Rob Cook	Scapa Flow, Scotland

Table 2.2: Example images from UK of suspected, low quality or uncertain Annex I biogenic *Modiolus modiolus* reef habitat discussed at the 2014 inter-agency *M. modiolus* workshop, presented in Section 4.

Reef Form	Image	Location
Uncertain or low quality Annex 1 reef. 'Clumps' of live *M. modiolus* in regular patches and high abundance, bound with dead mussels, which are difficult to decipher from the inter-clump cobble and pebble substrate.	 © Rob Cook	Scapa Flow, Scotland
Semi infaunal reef, partially buried and well dispersed with a mixture of live and dead *M. modiolus* and some associated species	 © JNCC/Cefas	Mid St George's Channel, Irish Sea
Potential sand inundated live reef with some dead shell, with some associated fauna evident through sand inundation.	 © NRW	12nm off North Anglesey, Irish Sea

Table 2.2 (contd.): Example images from UK of suspected, low quality or uncertain Annex I biogenic *Modiolus modiolus* reef habitat discussed at the 2014 inter-agency *M. modiolus* workshop, presented in Section 4.

Reef Form	Image	Location
High density of *M. modiolus* bed, live *M. modiolus* evident in stills, but also high sediment cover making it very hard to identify from video.	 © NRW	North Llŷn, Wales, Irish Sea.

Table 2.3: Example images from UK showing certain 'clumps' of Annex I biogenic *Modiolus modiolus* reef habitat.

Reef Form	Image	Location
M. modiolus forming regular 'clumps' with densities of live individuals more than 10 per m^2.	 © SNH	Sullom Voe, Scotland
M. modiolus forming regular 'clumps' with densities not visible easily from imagery.	 © Bernard Picton	Strangford Lough (prior to dredging), Northern Ireland

Table 2.4: Example images from UK showing certain 'bioherms' of Annex I biogenic *Modiolus modiolus* reef habitat.

Reef Form	Image	Location
M. modiolus forming a continuous 'bed' with high abundance of live bound individuals with cryptic/encrusting associated epifauna.	 © SNH	Noss Head, Scotland
M. modiolus forming regular 'clumps' with densities not visible easily from imagery.	 © Bernard Picton	Strangford Lough, Northern Ireland
M. modiolus forming 'bioherm' reef with dense, abundant live individuals in byssal aggregations, covering a large area, with abundant and diverse associated fauna.	 © NRW	12nm off North Anglesey, Irish Sea

Table 2.4 (contd.): Example images from UK showing certain 'bioherms' of Annex I biogenic *Modiolus modiolus* reef habitat.

Reef Form	Image	Location
M. modiolus forming 'bioherm' reef with dense, abundant live individuals in byssal aggregations, covering a large area, with abundant and diverse associated fauna.	 © Rob Cook	North Llŷn, Wales, Irish Sea.
M. modiolus forming a continuous 'bed' or 'bioherm' with superabundant dead man's fingers (*Alcyonium digitatum*)	 © JNCC/Cefas	Mid St George's Channel, Irish Sea

3 Workshop Summary

On March 4 and 5 2014, JNCC organised an inter-agency workshop on "Defining Annex I biogenic *M. modiolus* reef habitat under the Habitats Directive" at Natural Resources Wales' (NRW) Bangor Office. Sixteen attendees took part over the two days (Appendix 2), including representatives from Statutory Nature Conservation Bodies (JNCC, NRW and the Department of Environment Northern Ireland, DOE NI), Universities (Heriot-Watt University, Bangor University and Queen's University Belfast) and consultancies regularly working with *M. modiolus* (CMACS and Marine EcoSol). Prior to attending, agency participants were asked to provide typical *M. modiolus* reef images, contribute to a summary table of key features of what their agency does and does not currently consider Annex I biogenic *M. modiolus* reef, and prepare ideas for best survey practise. These were collated by JNCC for discussion at the workshop.

Over the two day workshop, a series of presentations and discussions considered how to:

1. Clarify whether OSPAR and UKBAP *M. modiolus* 'beds' and Annex I biogenic *M. modiolus* 'reef' habitat definitions are the same for the purposes of the tool developed over the workshop.
2. Develop a clear decision process to aid agencies in identifying what is most likely and unlikely to be Annex I biogenic *M. modiolus* reef habitat.
3. Decide whether a 'reefiness' tool similar to the *Sabellaria spinulosa* (Gubbay 2007) or stony reef (Irving 2009) tools was required. If so, to discuss how best this would be developed, and whether condition or quality of reef should be incorporated into such a tool.
4. Provide guidance on the most appropriate survey methods for identifying (not monitoring) Annex I biogenic *M. modiolus* reef habitat.

The following presentations were provided:

Difficulties in defining Annex I biogenic *M. modiolus* reef

- Defining Annex I biogenic *Modiolus* reef habitat. Laura Robson, JNCC.
- Annex I biogenic *Modiolus* reef: Geographical variation & interpretation. Dan Bayley, JNCC with contributions from SNH (Scottish Natural Heritage), NRW and DOE (NI).
- Is it or isn't it? A case study from NW Anglesey. Kirsten Ramsay, NRW.
- SEA6 2005 North Anglesey Survey. Ivor Rees, Independent (formally Bangor University)
- *Modiolus*: Where have all the mussels gone? Strangford Lough techniques and lessons learnt. Joe Breen, DOE (NI).
- The difference in communities in Strangford Lough: Pre and post damage. Jose Farinas Franco, Heriot-Watt University.

Survey methods to define Annex I *M. modiolus* biogenic reef habitat

- Use of side-scan sonar and multibeam to estimate the extent and formation of Annex I biogenic *Modiolus* reef and detecting physical impacts. Charlie Lindenbaum, NRW.

Defining 'reefiness' and condition using different methods

- Consideration of a 'Reefiness' assessment. Laura Robson, JNCC.
- *Modiolus* reef density and community indicators of Good Environmental Status. Jose Farinas Franco, Heriot-Watt Uni.

Current research projects

- Vulnerability of *Modiolus* reefs to climate change: from mechanisms to management strategies. Clara Mackenzie, Heriot-Watt University.

- *M. modiolus* research in Bangor University. Coleen Suckling & Andrew Davies, Bangor University.

Discussions were used to produce a final identification tool (Box 4.2) and the accompanying rationale provided in Section 4. Appendix 1 provides the Agenda and Annex 1 (separate document) a detailed summary of presentations and discussions used to inform the final decisions.

4 Brief guidance for positive identification of Annex I biogenic *M. modiolus* reef habitat and rationale

Workshop presentations and discussions informed the rationale for a guidance tool, enabling the positive identification of Annex 1 biogenic *M. modiolus* reef habitat (Boxes 4.1 and 4.2).

4.1 What makes a *M. modiolus* reef an Annex I habitat?

The first conclusion from discussions regarding OSPAR and UKBAP *M. modiolus* 'beds' and Annex I 'reef' definitions (Boxes 2.1 and 2.2), were that they have been described synonymously, and are the same for the purposes of the resulting tools.

A revised working definition of Annex I biogenic *M. modiolus* reef habitat was agreed by delegates:

*"*Modiolus modiolus *is the foundation species in biogenic reefs that are characterised by clumped mussels and shell covering more than 30% of the substrate, which may be infaunal or embedded reefs, semi-infaunal (with densities of greater than five live individuals per m^2) or form epifaunal mounds (standing clear of the substrate with more than 10 live individuals per clump), all of which support communities with high species richness (or diversity) compared to sediments of the surrounding area".*

These criteria formed the basis of the brief guidance tool described in the following sections. Boxes 4.1 and 4.2 provide guidance on how to apply the criteria to survey data or images.

4.1.1 Rationale behind guidance on the identification of Annex I biogenic *M. modiolus* reef habitat.

It was agreed that there were three initial factors considered to be of **primary importance** in defining a *M. modiolus* reef, regardless of condition or location, so were taken forward as the first stage of identifying the Annex 1 habitat (Table 4.1):

- Live adult *M. modiolus* individuals are present;
- The biota/communities are distinct from the surrounding habitat; and,
- The distinct region containing *M. modiolus* is greater than 25m^2 in extent.

Following these three primary identification criteria, there was still some discrepancy over what should be considered as Annex 1 habitat, mainly confused by either the type of reef formation, or the suite of prevailing environmental conditions experienced by the reef. Before any guidance could continue, it was decided that the tool should split the characterising criteria based on reef form. The tool was therefore split by open coast and sheltered / semi-enclosed reefs.

Further discussion considered the factors that were considered to be of **secondary importance** to identify either an open coast or sheltered Annex 1*M. modiolus* reef habitat, if all the primary importance identification criteria were met. Percent cover of reef, or patchiness; abundance (number of live individuals); acoustic signature and elevation, were all considered key descriptors.

With these conclusions regarding patchiness, percent cover, abundance and elevation, the guidance provides a definition of an area of *M. modiolus* with some confidence that is likely to be classified as Annex 1 biogenic reef habitat, and when an area is unlikely to be considered Annex 1 biogenic reef habitat(Box 4.2).

4.1.2 Stage 1 assessment: Factors considered of primary importance in defining Annex I *M. modiolus* reef habitat.

Table 4.1: The three core assignment criteria considered to be of **primary importance** in defining *M. modiolus* reef

Presence of live adult *M. modiolus*	**The biota/community should be distinct from the surrounding habitat**	**The distinct region containing *M. modiolus* is greater than 25m^2 in extent**
The consensus from all contributors was that adult, and therefore established, live *M. modiolus* are essential to identifying the aggregation as an Annex I biogenic reef habitat (i.e. dead shell only, or solely juvenile individuals cannot be considered *M. modiolus* reef). The fundamental ecology of the *M. modiolus* reef is the presence of adults binding the biogenic reef and substrate together with their byssus threads, with varying amount of juveniles and dead shell. If there is no evidence of live mussels in a reef formation, the binding byssal threads will quickly disintegrate and the reef feature will be lost. The proportion of live and dead shell is difficult to assess from imagery, and therefore not deemed as important as the confirmed presence of live adults in any reef formation.	All conservation initiative guidance and descriptions currently describe *M. modiolus* beds and reefs as having increased or rich diversity of species and/or evidence of zonation of species. As there is such geographic variation in community structure for *M. modiolus* beds (described, but not in full, by the JNCC biotopes, Connor *et al* 2004), the workshop group discussed if it was necessary to quantify this diversity for Annex I habitat identification purposes, or whether the quantification of community structure was more important for further monitoring. Additionally, the diversity and community structure will vary significantly depending on which assessment method is used (infaunal cores, poor video quality, high resolution stills or dive survey). All participants agreed that generally the increased complexity of the reef structure means that the community associated with mussel reef is different to that of surrounding habitats, and a qualitative approach to identifying this difference could be used. However, the comparative 'surrounding habitats' must be a reasonable distance from the reef, as the reef feature influences the interstitial diversity and the habitats 'between clumps'.	JNCC's Habitats Directive SAC guidance suggested that the best examples in extent and quality of UK habitat types of interest should be designated in the SAC network, and that the minimum area for designation would be feature specific (McLeod *et al* 2005*)*. However, with shifting baselines of information, this is neither practical nor consistent. For the purposes of defining an Annex I reef habitat, the generally accepted area in the UK is >25m^2 (Foster-Smith *et al* 2007; OSPAR 2008; Irving 2009). However, it is very difficult to cover such large areas of a potentially patchy habitat without some minimum guidance for acoustic, video and dive surveys. The OSPAR background document for *M. modiolus* beds (OSPAR commission, 2009) detailed available survey methods in Annex 2, but technology has swiftly moved on and many papers have been published since that may be more useful (Wildish *et al* 1998; Lindenbaum *et al* 2008; Sanderson *et al* 2008; Ramsay *et al*, in prep). Section 4.2 provides a summary of the best survey techniques to establish whether the feature of interest is greater than 25m^2.

4.1.3 Geographical location

Is the reef on open coast or in a sheltered or semi-enclosed area?

Holt *et al* (1998) described two main *M. modiolus* bed and reef forms, one of which is considered 'semi infaunal'. Other reports speak of true reefs sometimes forming 'bioherm' waves elevated over 1m above the surrounding seabed. Workshop participants discussed whether the key feature for an Annex I biogenic reef habitat is the topographical distinctness, reef form (infaunal or bioherm) or geographic region, or whether these can or should be compounded into one key criterion for purposes of an identification tool. It was concluded, following presentations from different nature conservation agencies around the UK and from discussions with university researchers, that there are two main types of reef, those on open coasts (such as off the North Llŷn Peninsula in Wales, and Noss Head in Scotland) and those formed in more sheltered but tidally swept areas (including Strangford Lough and Loch Alsh).

The criteria for defining Annex I 'sheltered' or 'open coast' *M. modiolus* reef habitat appeared to differ in the opinions of the participants, and therefore, before moving onto considering the reef in any more detail, it was agreed that the next step would be to decide whether a reef is open or sheltered in its location.

4.1.4 Stage 2 assessment: Factors considered to be of secondary importance in defining Annex I *M. modiolus* reef habitat, if all the primary importance assignment criteria are met

Percent cover/patchiness:

'Clumping' reef may be sparse and small (such as those remaining in Strangford Lough, Table 2.3), whereas 'bioherms' may be extensive but formed of undulating 'waves' (such as those off the North Llŷn, Table 2.4). Both of these can be patchy, for instance if a video tow ran through a 'trough' of a bioherm's wave structure, or between clumps of reef habitat. The workshop group decided that, for this reason, patchiness (over a large area) could be accounted for by assigning the Annex I feature with a confidence level. Jose Fariñas-Franco (Heriot-Watt University) has been working on indicators of Good Ecological Status for *M. modiolus* reef, to meet requirements of the Marine Strategy Framework Directive, for the Healthy and Biologically Diverse Seas Evidence Group (HBDSEG). In doing this work, and other research, he has looked at the variability of reefs across the UK and northern Europe (in preparation for publication by JNCC in 2014).

Following discussion, Fariñas-Franco concluded that on **open coasts**, where *M. modiolus* is generally consistently undulating or creating waved 'bioherms' (for example at Noss Head), there is greater than 30% cover of the area that would currently be considered biogenic reef (aggregation of *M. modiolus*, shell and other fauna distinct from the surrounding sediment, both in terms of abundance and diversity). Following further interrogation of the Fariñas-Franco's data set, where percentage cover was assessed from towed imagery transects, it was concluded that at over 70% cover, the associated community and abundance of live shell ensured high confidence that this is a good example of Annex I *M. modiolus* biogenic reef habitat.

Assessing percent cover of 'clumping' reefs in more **sheltered environments** is more difficult. Fariñas-Franco's research from Strangford Lough found that at a percentage cover greater than 40% (over a large area, assessed by his team on towed imagery transects), the community was significantly different to the surrounding sediments outside the area of suspected reef, and therefore there was high confidence that this area of reef would be

identified as Annex I reef habitat. However, in some cases significant differences were also found in areas with as low as 5% cover of *M. modiolus*. In these situations the surrounding sediments were generally very muddy and devoid of other complexity. Therefore it was concluded that a scale of 5-40% cover of *M. modiolus* clumps in an area greater than 25m^2 would be of medium confidence Annex I reef habitat. Anything less than 5% is unlikely to be Annex I reef habitat.

Abundance/density of (live) individuals (small scale/cover):

The assessment of abundance of live *M. modiolus*, and the importance of the number of live individuals over different scales, was discussed in depth during the workshop. Variation has been found in abundance depending on the method used, there can also be considerable inter-surveyor variability depending upon the experience of the surveyor. As part of Jose Fariñas-Franco's (Heriot-Watt University) work on indicators of Good Ecological Status, Fariñas-Franco looked at inter-surveyor variability, variability in abundance assigned from differing methods, and correlations in diversity indices with abundance of *M. modiolus*. Fariñas-Franco's team found that in sheltered, clumping reefs at least ten live mussels per clump gave an asymptote in diversity (peak Margelef's richness, Evenness & Shannon-Weiner index, unpublished data Heriot-Watt University & JNCC). His team found that diver counts found 2-3 times fewer live *M. modiolus* than when removing and counting all individuals within a known area. It is therefore likely that abundance assessments using imagery analysis or diver *in situ* counts would underestimate the actual abundance of *M. modiolus*. As a result, any areas of 'clumps' with greater than 10 individual *M. modiolus* per clump, could be considered Annex I reef habitat. However, this rationale does not transfer to areas of open coast *M. modiolus,* but was deemed important to assist in confident assignment of Annex I reef habitat in sheltered and 'clumping' reefs.

In Scotland the current guidelines specify that anything less than five animals per m^2 is unlikely to be Annex I *M. modiolus* reef habitat. The guidelines also state that anything more than nine live individuals per m^2 can be assigned as Annex I reef habitat with confidence. It was decided that these guidelines should be left in place as guidance for the open coast reefs (as density rules will not work successfully for clumping sheltered reefs).

Acoustic signature:

Acoustic data, if recorded and processed properly, can be informative to identify areas of suspected *M. modiolus* and assess its potential extent. However, acoustic data cannot be used as the sole source of evidence for identification of Annex 1 biogenic *M. modiolus* reef habitat. Similarly, acoustic data is not essential for successful identification (although it is advised to provide a baseline for future comparison in the event of damage). Side-scan sonar tends to show distinctive 'rippling' of the seabed around bioherm *M. modiolus* reef and multibeam data can be informative if processed and interpreted correctly.

It was decided that if there was a distinct acoustic signature together with one other criteria of a likely *M. modiolus* reef habitat, then practitioners could be confident that the area is probably of Annex I biogenic *M. modiolus* reef habitat.

Elevation:

Topographic distinctness, or elevation from surrounding substrate, is deemed important in assessments of other types of Annex I 'reef' habitat. However, beds of *M. modiolus* can be barely elevated from the surrounding seabed (1cm). Therefore the question remains, what topographical distinctness or elevation should be required for identifying Annex I *M. modiolus* reef habitat? Previous definitions of Annex I reef habitat (stony and *Sabellaria*

spinulosa) have required elevation as an identification criterion, however with *M. modiolus* reefs it is the provision of hard substrata bound together by byssus and forming topographic complexity that mostly creates the reef, not the degree of elevation. Holt *et al (*1998) described two main *M. modiolus* bed and reef forms, one of which is considered 'semi infaunal'. Other reports speak of true reefs sometimes forming bioherm waves elevated over 1m above the surrounding seabed.

The consensus amongst participants regarding assessments of elevation was that even with acoustic data and *in situ* diver surveys, elevation is very hard to measure and therefore any guidance on this should not be too prescriptive. In order to address this, elevation has been included as the final secondary assessment criterion. Where a reef of no elevation is situated in open coast, it is unlikely to be considered Annex I reef habitat. With increasing elevation from the seabed, there is greater confidence in the Annex I identification. In sheltered and semi-enclosed *M. modiolus* habitats, the clumps are always elevated from the (usually muddy) seabed.

4.1.5 Brief guidance for positive identification of Annex I biogenic *M. modiolus* reef habitat.

As a result of discussions on what makes *M. modiolus* reef an Annex I reef habitat (Section 4.1.1), a two stage approach was decided upon: the first stage to ensure that the area meets basic primary *M. modiolus* reef criteria regardless of geographic location or environmental variation; and the second stage to ascertain whether the suspected biogenic reef is likely or unlikely to be Annex I reef habitat, with varying indicators depending on the type of location ('open coast' or 'sheltered/semi-enclosed').

Following discussions, it was agreed that a score or assignment of confidence would be useful for practitioners to describe their suspected reef habitat to the agencies. Therefore the final guidance uses the 'likelihood' of an area being Annex I reef habitat (unlikely or likely), and the associated 'confidence' in the area being of Annex I reef habitat (uncertain, medium or high). An area with two or more secondary selection criteria of high confidence will almost certainly be Annex I biogenic *M. modiolus* reef, assigned therefore with high confidence. The word 'confidence' must not be confused with the word 'quality'. The basic guidance for identification deliberately avoided the term 'quality' as this would become part of ongoing monitoring and assessment of Good Environmental Status, rather than the initial identification.

Finally, upon reflection on the guidance, it was deemed that there are occasions when an area of likely Annex I reef habitat might be identified, but where either lack of high confidence evidence, e.g. evidence coming from the edge of a reef formation, or an area where recent damage or recovery has occurred, may mean that two 'likely' criteria are not found. However, there could be only one high confidence likely criterion and three uncertain criteria, reducing the resulting confidence in the identification of Annex 1 reef habitat of the area to 'unlikely'. Therefore, a scoring system was developed to ensure that suspected reef habitat gets a 'second chance' for positive identification. It was decided that if the total 'score' of a suspected area was greater than six then it is likely to be Annex I biogenic reef habitat, but that further evidence may be required prior to management decisions being made.

The identification process is clarified by utilising the Boxes that follow:

- Box 4.1 provides 'instructions of how to use the following brief guidance'.
- Box 4.2 presents a brief guidance on identification, but the assessment criteria must be used in conjunction with Box 4.1.

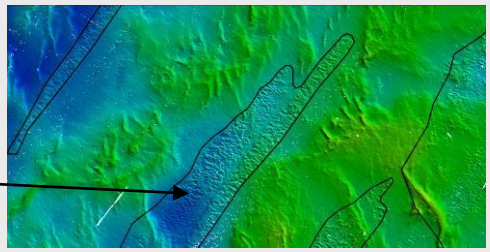
Tables 4.2 and 4.3 provide example images of what should and should not be considered Annex I biogenic *M. modiolus* reef habitat and rationale for decision making utilising the guidance provided in Boxes 4.1 and 4.2.

Box 4.1: Instructions for the use of 'Brief guidance for positive identification of Annex I biogenic *M. modiolus* reef habitat'.

Instructions for the use of Box 4.2:

- **Survey area** of suspected Annex I biogenic *M. modiolus* reef habitat (see section 4.1.1 for guidance and rationale).
- **Are all essential criteria specified in Stage 1 met?** If 'Yes', go to Step 2, if 'No' then this is not an Annex I *M. modiolus* reef feature.
- **Decide whether the location of possible biogenic reef is** open coast or sheltered / semi-enclosed.
- **Complete Stage 2 Assessment** for each site, either open coast or sheltered *M. modiolus*. Within the location:
    - at least two 'Likely' categories must be met to be considered Annex I *M. modiolus* reef,
      OR
    - the total score for the location should add up to 6 in order to be potential Annex I Biogenic Reef, which would require further evidence/work.

It is possible for an area to score '6' if it has three uncertain characteristics, but one 'high confidence' characteristic. For example, an area on the open coast might have less than 30% cover of biogenic reef structure (or difficult to tell), have no distinct acoustic signature, and no elevation, but there could be embedded *M. modiolus* of >9 individuals per m^2 in some seabed imagery. In this case, it is likely that this could be Annex I biogenic *M. modiolus* reef habitat, but further evidence/work in the area would be required to be highly confident.



Guidance on acoustic signature:
A 'distinct acoustic signature' can be identified as 'ripples' on side scan sonar or multi-beam if the resolution is high enough (as shown by the arrow in the insert).

Additional notes on the brief guidance:

- No specific biota (except *M. modiolus*) is particularly important in defining reef habitat (as it varies so much geographically and depending on the physical characteristics of the area), but it needs to meet the criteria that 'the biota or community is distinct from the surrounding habitat' (as specified in Stage 1).
- If there is good evidence that a questionable area of *M. modiolus* was recently identified as Annex I reef habitat but may be damaged, then this should be flagged up in the habitat description.
- Unlikely Annex I reef habitat, or areas of low confidence reef, may be indicative of the edge of a larger reef habitat, therefore further ground truthing may be required to determine confident assignment.

Confidence:

- 'Confidence' in the identification of Annex I reef habitat must not be confused with quality or condition. The identification guidance sought to avoid assigning quality or condition of a reef, as this will be covered by forthcoming Marine Strategy Framework Directive guidance on indicators of Good Environmental Status.

Box 4.2: Brief Guidance for positive identification of Annex I biogenic *M. modiolus* reef habitat. (These criteria must be used in conjunction with 'Instructions of how to use Guidance' in Box 4.1)

STAGE 1: ANNEX I BIOGENIC *M. MODIOLUS* REEF HABITAT CRITERIA

ALL Stage 1 criteria are required to be met for an area to be considered biogenic *M. modiolus* reef habitat:

- Live adult *M. modiolus* individuals are present;
- The biota/communities are distinct from the surrounding habitat!
- The distinct region containing *M. modiolus* is greater than 25m^2 in extent

STAGE 2: ASSESSING CONFIDENCE FOR ANNEX I DESIGNATION

Either: At least two 'Likely' categories must be met to be considered Annex I *M. modiolus* reef habitat

OR: the total for this section must add up to 6 in order to be Annex I biogenic reef habitat

Location:	**Open coast *M. modiolus***			**Sheltered/Semi-enclosed *M. modiolus***		
Examples:	*North Llŷn, Noss Head Scotland, Scapa Flow*			*Sea lochs/loughs/voes*		
Likelihood of Annex I reef habitat:	*UNLIKELY*	*LIKELY*		*UNLIKELY*	*LIKELY*	
Confidence in being reef habitat:	***Uncertain***	***Medium***	***High***	***Uncertain***	***Mediu m***	***High***
Score:	***1***	***2***	***3***	***1***	***2***	***3***
Percent cover of suspected biogenic reef (over an area >25m^2):	**<30%*** is suspected biogenic reef (aggregation of *M. modiolus*, shell and other fauna distinct from the surrounding sediment). With low percentage cover you would expect to see clumped *M. modiolus* and attached epifauna (based on the Noss Head data of edge and dense reef).	**30-70%**	**70-100%**	**<5%** (clumps in an area >25m^2) (Based loosely on Strangford Lough and HBDSEG GES indicators work)	**5-40%**	**>40%**
No of individuals of *M. modiolus* per clump	n/a	n/a	n/a	**>3**	**>10**	**>10**
No of individuals per m^2 (small scale, i.e. quadrats or core samples) †:	**<5**	**5-9**	**>9**	n/a	n/a	n/a
Distinct acoustic signature:	No	**Yes**	**Yes**	No	**Yes**	**Yes**
Elevation:	No elevation	**Low relief** (Some level of protrusion)	**High Relief** (Distinct wave form/ noticeably elevated)	**Elevated** (usually from mud)	**Elevated** (usually from mud)	**Elevated** (usually from mud)

! 'Surrounding habitat' encompasses sediments and substrates, biota should be taken quite far away, as the immediate inter-reef habitats are influenced by the reef itself.

* If there is good evidence that the area has been a reef recently (previous to a disturbance event), this should be flagged up.

† Be wary of using remote imagery to assess this criteria as methodology and equipment used to determine this could vary. Counting individuals from stills/video is often inaccurate and is therefore not recommend. (When compared divers found 3-4x the number of individuals than those identified from images. Diver counts are likely to underestimate the number of individuals compared to when removing and counting all individuals within a known area).

Table 4.2.a: Examples of 'Likely' and 'Unlikely' Open Coast Annex I biogenic *Modiolus* reef

Likelihood of Annex I quality:	**Unlikely**	**Likely**	
Confidence in being reef habitat:	**Low**	**Medium**	**High**
Scottish examples	 Photo: Rob Cook **Isolated clumps of *M. modiolus*, Scapa Flow, Scotland** Low percentage cover of reef structure comprising clumped *M. Modiolus* in densities less than 5m^2, but with some attached epifauna. Little or no significant elevation from surrounding area.	 Photo: Marine Scotland Science **Low lying *M. modiolus* reef structure Noss Head, Marine Scotland** A large area of low lying live *M. modiolus* reef-like structure, almost 100% cover in places. Large epifauna not easily identified or recognised on video, but high resolution stills analysis found very high density of live *M. modiolus* and the encrusting epifauna is significantly different from that of surrounding area.	 Photo: Jose Fariñas- Franco **Dense 'bioherm' of *M. modiolus* reef, Scapa Flow** Definite abundance of live *M. modiolus* with a high percent cover of reef structure elevated from the surrounding seabed over a large area with a diverse associated epifauna. Diver surveys confirm densities of *M. modiolus* are >9m^2.

Table 4.2.b: Irish Sea examples of 'Likely' and 'Unlikely' Open Coast Annex I biogenic *M. modiolus* reef habitat

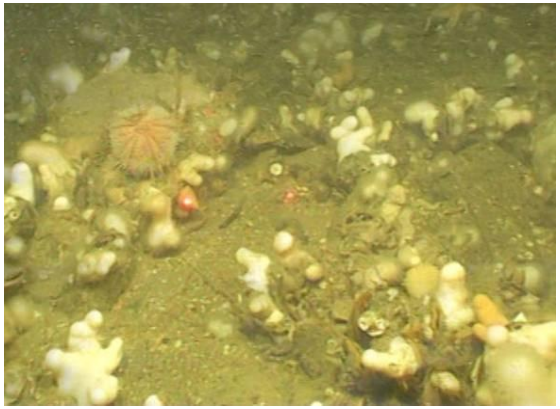
Likelihood of Annex I quality:	**Unlikely**	**Likely**	
Confidence in being reef:	**Low**	**Medium**	**High**
Irish Sea examples	 Photo: NRW ***M. modiolus* growing in and around cobble reef, offshore North Anglesey** This area is unlikely to be considered Annex I biogenic *M. modiolus* reef habitat. The substrates and conspicuous epifauna are not significantly different to that of surrounding coarse sediments (stage 1 requirement). Percent cover of the structure is <30% of the area of interest (not the individual image, but the whole area surveyed.). The substrate which the 'proxies' *Alcyonium digitatum* are living on, is difficult to distinguish from cobbles compared to biogenic aggregations. However, the number of live *M. modiolus* individuals is >5m^2 from imagery and Depth of over 90m below sea level restricts survey effort, but ideally further sampling (high resolution images) or diving might increase confidence in this assignment.	 Photo: NRW ***M. modiolus* reef structure forming a 'bioherm' largely of dead shell, offshore North Anglesey** A large area of largely dead but also live shells forming a reef like structure. Percent cover of the structure is >30% of the area of interest, with low relief from the surrounding seabed, but number of live *M. modiolus* individuals is <5m^2 from imagery and the large epifauna are significantly different to that of surrounding coarse sediments. Depth of over 90m below sea level restricts survey effort, but ideally further sampling (high resolution images) or diving might increase confidence in this assignment.	 Photo: Rohan Holt, NRW **Dense 'bioherm' of *M. modiolus* reef, Point of Ayre, Isle of Man** Definite abundance of live *M. modiolus* with a high percent cover of reef structure elevated from the surrounding seabed over a large area with diverse associated epifauna. Diver surveys confirm densities of *M. modiolus* are >9m^2.

Table 4.3: Examples of 'Likely' and 'Unlikely' Sheltered and Semi-enclosed Annex I biogenic *M. modiolus* reef habitat

Likelihood of Annex I quality:	**Unlikely**	**Likely**	
Confidence in being reef habitat:	**Low**	**Medium**	**High**
Sheltered coast examples	 Photo: Jose Fariñas- Franco ***M. modiolus* embedded in surrounding sediments, Strangford Lough (Selk Rock)** It would not be possible to make a definite decision based on this one image. This area has a low percent cover of the structure (<30% of the area of interest). However, the number of live *M. modiolus* individuals is <3 per clump from this single image. As live individuals are embedded into the sediment, the feature has low relief, so only scores 4 on the Stage 2 assessment and is unlikely to be considered Annex I biogenic *M. modiolus* reef habitat. However, this could be on the periphery of a larger feature and more imagery and a wider search area would be suggested.	 Photo Strangford Lough (round Island Pinnacle): Jose Fariñas- Franco **'Clumps' of *M. modiolus* forming a sparse reef structure.** 5-40% cover of small 'clumps' of *M. modiolus* elevated from the seabed, detectable using acoustics. More than 10 live *M. modiolus* per clump, with distinct community assemblages different from the sediments of the surrounding area.	 Photo Strangford Lough: DOE (NI) **Closely packed 'clumps' of *M. modiolus* reef.** Tightly packed 'clumps' of *M. modiolus*, almost forming a 'bioherm', covering greater than 40% of the area of interest. A distinct acoustic signature as elevated from the seabed.

4.1.6 Additional criteria considered

The following potential criteria were explored but discounted as not being imperative to the identification guidance:

Depth:
Depth restrictions or guidance have been provided in previous reports. OSPAR and UK BAP state that *M. modiolus* may form dense beds up to 70m below sea level. However, Scotland has acknowledged in their Marine Atlas of Habitats of Principal Importance (Baxter *et al* 2011) that *M. modiolus* can form beds to 100m depth. It was concluded that this is not a good criterion for identification of the Annex I habitat as *M. modiolus* beds have since been found at depths greater than 200m below chart datum (Ivor Rees, *Pers. Comm.*).

The edge effect:
The abundance, percent cover, elevation and community can all vary towards the edge of a *M. modiolus* reef. Hopefully the scoring part of the second stage guidance will account for the edge effect, and flag areas where more surveying may be required before high confidence can be assigned to a potential Annex I biogenic *M. modiolus* reef habitat identification.

Use of proxies:
In some cases *M. modiolus* 'reef' is not easily defined or identifiable from limited resources or survey quality, and the possibility of using more easily identified 'proxy' species (e.g. *Alcyonium digitatum*) to assign Annex I reef habitat was discussed. The conclusion for this across the board was that this is not appropriate, unless a lot of ground truthing has been done on the same bed previously. *Alcyonium digitatum,* for instance, can be present on some beds but not others in relative close proximity, but the presence of cobbles (also difficult to see on poor quality imagery) can confuse the proxy and any counts may overestimate the presence of *M. modiolus* in an area of hidden cobbles amongst dead shell.

Ecosystem functioning and services:
OSPAR: "Mosaics also occur where frequent smaller clumps of mussels so influence ecosystem functioning that for conservation and management purposes lower thresholds can be accepted".

It was deemed by participants that ecosystem functioning was not a practical concept to assess at the stage of initial assessment of Annex I reef (although the modification of the associated community and likely increase in biodiversity is part of the assessment). The reason for protection of Annex I biogenic *M. modiolus* reef habitat is in itself a result of the ecosystem functioning and services delivered by the reef feature.

Specific geographical variation:
Specific geographical variation was discussed. The location in terms of environmental exposure seemed more important to the reef functioning than the specific geographical variation. The aim was to create guidance which avoided having to address specific geographical variation, to ensure a generic guide which is consistent across the country. Therefore open coast and sheltered *M. modiolus* were the chosen criteria.

Biotope variation:
Variations in *M. modiolus* biotopes were discussed, as were problems with some biotope assignment (i.e. subjectivity between surveyors, and the fact that some biotopes are described based on infaunal sampling, whilst others on epifaunal samples). Some areas of *M. modiolus* do not fit well into any JNCC biotope and therefore the biotope was not deemed an essential criterion for designation.

Siltiness and sand inundation:
OSPAR: "Individual M. modiolus *most often live partly buried in the sediment".*
*BAP: "*M. modiolus *can occur as relatively small, dense beds of epifaunal mussels […] but is more frequently recessed at least partly into mixed or muddy sediments in a variety of tidal regimes".*
OSPAR: "Substantial accumulations of dead shell often occur in and around the long established beds".

Defining *M. modiolus* beds where the mussels are buried or partly buried can be difficult (Ramsay *et al*, in prep). How can the extent of buried *M. modiolus* be defined, and are buried or inundated *M. modiolus* definitely healthy or even alive? Can areas comprising mostly dead shell be designated, and if so how best can they be certainly defined? The conclusions were that this is difficult to assess and to conclude if the reef is alive. If the guidance in Boxes 4.1 and 4.2 are followed then a clear assessment should be possible upon the evidence, rather than what is missed by the evidence.

4.1.7 Assigning 'reefiness', quality or condition of *M. modiolus* reef.

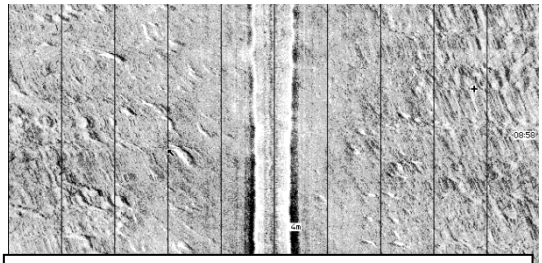
Delegates agreed that the development of a scale of 'reefiness', quality or condition was beyond the scope of the current workshop. The monitoring of Good Environmental Status (towards the Marine Strategy Framework Directive, EC Directive 2008/56/EC) in future will help to monitor the status of designated reefs. Monitoring quality will not be a part of the initial assignment of Annex I reef. Heriot-Watt University has been exploring *M. modiolus* reefs around the country to develop indicators of condition and quality towards monitoring Good Environmental Status, the final report for which will soon be available on the JNCC website.

4.2 Recommended survey methods to assist in confident identification of Annex I biogenic *M. modiolus* reef habitat.

Workshop participants recognised that some minimum guidance would be useful for acoustic, video and dive surveys. The *Modiolus modiolus* beds background document for the OSPAR Commission (2009) details available survey methods in Annex 2, but technology has swiftly moved on, and many papers have been published since, which may be more useful (in 2014). Examples of suggested methods include Wildish *et al (*1998), Lindenbaum *et al (*2008), Sanderson *et al* (2008), Ramsay *et al (*in prep).

It was decided by participants that suggested methods should not be too prescribed. Table 4.4 presents brief advice and rationale for the best perceived methods (discussed during the workshop), to identify potential areas of *M. modiolus* reef habitat and to estimate and ground truth the extent. Participants agreed that side-scan sonar is often the best value for money and is usually able to highlight potential extent of *M. modiolus* for ground truthing. Ground truthing should be undertaken using well lit, forward facing video sleds accompanied by regular downward facing, good quality stills with analysis completed by experienced surveyors. If, following Boxes 4.1 and 4.2, there is still uncertainty regarding whether an area is Annex I biogenic *M. modiolus* reef habitat, then some diver surveys or cores may be necessary to confirm presence and abundance of live *M. modiolus*. Diving surveys would more commonly be aimed at monitoring or assessing the condition of a feature, rather than the initial identification of the Annex I habitat.

Table 4.4: Recommended survey methods to identify and assign Annex I biogenic *Modiolus* reef.

Reason for survey	Survey Method	Rationale for decision
Identify potential *M. modiolus* reef and baseline of extent	Side scan sonar is preferable as it usually picks up distinctive *M. modiolus* 'ripples' on the seabed.  **Image provided by Ivor Rees, from SEA6 2005 survey** (Rees 2005). (Multi-beam can be considered if processing method is of high enough resolution, to less than 2m, and interpreted by someone with experience of identifying *M. modiolus*)	Side scan sonar is relatively cheap, easy and more widely interpretable than multi-beam (Wildish *et al* 1998; Rees 2005; Lindenbaum *et al* 2008). Multi-beam is useful if assessed at 1m resolution (see Box 4.1) The DOE (NI) has a protocol for multi-beam processing and analysis which is handed out as an advisory document to developers, which may be a useful standard for other agencies in future.
Ground truthing	Well lit forward facing towed video with downward facing high resolution stills camera and strobes (and arrangement of strobe advice), as minimum.	The consensus was to use forward facing video with good lights, together with downward facing stills (minimum 250-300 dpi) at regular intervals. In poor visibility (turbid conditions)), a freshwater curtain camera (taking imagery through freshwater) gleans excellent results, but the lighting is hard to get right. High resolution ROVs are ok for basic assignment, but difficult to get any quantitative data from. Use the forthcoming NMBAQC guidance to advise on this (JNCC (in prep): NMBAQC Scheme: Epibiota Video Monitoring Best Practice guidelines).
Validating Ground truthing and Monitoring	Diving	Diving will never be sufficient to estimate the extent of live *M. modiolus* reef habitat but can be useful to ascertain density of *M. modiolus* and associated epifauna. It has serious depth, cost and extent limitations and is not essential for most assignment of Annex I biogenic *M. modiolus* reef.
Validating Ground truthing and Monitoring	Diver cores/sampling	Useful to validate whether a reef is live, collect real abundance and associated species data for small areas, but not essential for assignment of Annex I biogenic *M. modiolus* reef. However, this method will also cause damage to the reef and should be used sparingly.

4.3 Concluding remarks

The current report aimed to provide better guidance on how to positively identify Annex I biogenic *M. modiolus* Reef habitat under the EC Habitats Directive. It aims to make identification more coherent and consistent across the UK.

This guidance tool is also useful for the identification of OSPAR and UKBAP *M. modiolus* beds/reefs as it is likely any Annex I reef habitat identified through this tool will also fall within the scope of the current OSPAR and UKBAP habitat definitions.

The guidance provided should be used by those experienced in subtidal marine ecology and the horse mussel, *Modiolus modiolus*. Anyone with concerns over the identification of a suspected area of likely *M. modiolus* reef should get in touch with their local statutory conservation agency.

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Appendix 1: Agenda

Inter-agency workshop on Annex I *Modiolus* biogenic reefs
March 4th (10:00) - March 5th (16:00), 2014
A JNCC event at NRW, Maes y Ffynnon, Penrhosgarnedd, Bangor, North Wales.

Day 1: Defining *Modiolus* Reefs.
(Chaired by Laura Robson, JNCC. Rapporteur Liz Morris, Marine EcoSol)
The aim of the first day is to define Annex I *Modiolus* reef and identify any challenges associated to positive assignment regionally or in deeper waters. The resulting discussion points will set the priorities for the development of minimum survey and data requirements, and a 'reefiness' tool in day two.

10:00 Introduction: Welcome to the workshop and reasons for running it - (**Dan Bayley, JNCC; Kirsten Ramsay, NRW – venue intro)**

10:30What is Annex I *Modiolus* biogenic reef: *Modiolus* reefs in the context of the Habitats Directive - limitations of existing definition in SAC selection. Define terminology (OSPAR/EUNIS definitions etc)**.** **Followed by Q&A. Laura Robson, JNCC**

<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<<< **11:30 Tea & Coffee** >>

12:00 Examples of what is and isn't considered Annex I *Modiolus* biogenic reef: Geographical variation (with slides contributed from Wales, Scotland and Ireland). **Dan Bayley (JNCC) to present, all to discuss and contribute**

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13:45 Problems assigning Annex I *Modiolus* biogenic reef: an Anglesey Case Study. Kirsten Ramsay, NRW

14:30 Irish Case study – Strangford (tbc)? Dai Roberts / Joe Breen / Hugh Edwards??

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15:30 Group discussion on particular areas of difficulty in reef assessment. To create a bullet point list of key problems assigning Annex I reef, and geographical / agency differences. Discussion ideas include: minimum required areas and addressing patchiness, assigning live / dead reef (are proxies acceptable), problems associated with identifying reefs in areas of siltation, biotoping issues, deep v shallow methods and specification. Will be referred back to over day two of workshop.

17:00 End

Day 2 (am): Development of minimum requirements to define live Annex I *Modiolus* Reef

(Chaired by Kirsten Ramsay, NRW. Rapporteur Liz Morris, Marine EcoSol)

The aim of morning of the second day is to explore methods currently employed to assign and monitor reef, and establish a standard suggested methods in terms of minimum survey area, type, data and quality requirements.

09:00 Summary of Day 1. Reminder of major outcomes of day one, and focus of day two. Liz Morris.

09:15 *Modiolus* reef density and community indicators of Good Environmental Status. Summary of recent work undertaken by Heriot-Watt University for the JNCC. What are the best indicators and how should they be measured? **Jose Farinas Franco, Heriot-Watt Uni.**

10:00Current / recent *Modiolus* work being undertaken by Bangor University. Can this information feed into standard monitoring? **Coleen Suckling, Bangor University**

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10:30 Use of Side-scan Sonar and multibeam to estimate the extent and formation of Annex I *Modiolus* biogenic reef and detecting physical impacts. Are there minimum quality requirements? What are the recommended standards and limitation? How can this be cost effectively ground truthed, and to what minimum requirements? **Charlie Lindenbaum, NRW.**

10:50 Discussion: What should minimum standard recommended survey type and area be to assign, and monitor, Annex I Biogenic reef? Bringing together the concerns from day one and the previous three talks to establish a Standard Operating Procedure for a) minimum survey area, b) minimum technique to be employed and c) minimum data quality for interpretation, for recommendation to contractors and developers.

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Day 2 (pm): Development a 'reefiness' scoring system for Annex I *Modiolus* Reef

(Chaired by Dan Bayley, JNCC. Rapporteur Liz Morris, Marine EcoSol)

The aim of the final session to is, taking into account the previous two sessions, whether a 'reefiness' scoring system similar to that used for *Sabellaria spinulosa* and stony reefs is applicable to *Modiolus* Annex I biogenic reef, and if so, what recommendations can we make to take this forward.

12:45 Consideration of relevance of scoring system used for *Sabellaria spinulosa* reefs and Stony reefs to interpretation of *Modiolus* reefs. Is this useful for *Modiolus* reef? Introduction to *Sabellaria spinulosa* and stony reef scoring system, and identification of useful bits to *Modiolus*. Laura Robson, JNCC.

13:15 Interactive session to identify 'reefiness' assessment tool for *Modiolus* reef habitats. Laura Robson, JNCC

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14:15 Continuation of interactive session to identify 'reefiness' assessment tool for *Modiolus* reef habitats. Laura Robson, JNCC

15:00 Agreement on characteristics and quantification of *Modiolus* reef habitats and the weighting of different characteristics in decision making.

16:00 End

Appendix 2: Participant List

AD	Andrew Davies Lecturer and Researcher in Marine Ecology	Bangor University	andrew.j.davies@bangor.ac.uk
CL	Charlie Lindenbaum Marine Monitoring, including diving and side scan.	NRW	Charles.Lindenbaum@cyfoethnaturiolcymru.gov.uk
CM	Clara Mackenzie PhD in Physiology of *Modiolus* (resilience and geanology)	Heriot-Watt University	clm32@hw.ac.uk
CS	Coleen Suckling Affects of climate change on *Modiolus*	Bangor University	coleen.suckling@bangor.ac.uk
DR	David (Dai) Roberts Bivalve restoration	Queens University	D.Roberts@qub.ac.uk
DB	Dan Bayley MPA Evidence Advisor	JNCC	Dan.Bayley@jncc.gov.uk
IR	Ivor Rees Retired but has had involvement in *Modiolus* since 1960s	Bangor University	ivorerees@hotmail.com
JB	Joe Breen NI Monitoring Officer	DOENI	Joe.Breen@doeni.gov.uk
JFF	Jose Fariñas-Franco Post doc. Modiolus ecology, developing good indicators of different reefs.	Heriot-Watt University	J.FarinasFranco@hw.ac.uk
KR	Kirsten Ramsay Subtidal Ecologist, designation of MPAs and casework	NRW	Kirsten.Ramsay@cyfoethnaturiolcymru.gov.uk
LR	Laura Robson Marine Habitats Advisor	JNCC	Laura.Robson@jncc.gov.uk
LM	Liz Morris	Marine EcoSol	info@marine-ecosol.com
NL	Natasha Lough Subtidal Ecologist	NRW	Natasha.Lough@cyfoethnaturiolcymru.gov.uk
RB	Rebecca Boys Student Intern	NRW	Rebecca.boys@naturalresourceswales.gov.uk
TH	Terry Holt Developed original SAC *Modiolus* guidance, currently working on windfarms and *Modiolus*	CMACS	tjholt@iom.com
MG	Matthew Green Reporting for SACs	NRW	Matthew.Green@cyfoethnaturiolcymru.gov.uk

Apologies but would like to hear outcomes

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Annex 1: Rapporteured Workshop Notes

Annex 1 is provided in a separate document entitled ‘Morris 2014 Annex 1_Workshop Rapporteured+

Notes.doc’, available from JNCC on request.