OSPAR COMMISSION

Background Document for *Modiolus modiolus* beds

Biodiversity Series

2009

OSPAR Convention

The Convention for the Protection of the Marine Environment of the North-East Atlantic (the "OSPAR Convention") was opened for signature at the Ministerial Meeting of the former Oslo and Paris Commissions in Paris on 22 September 1992. The Convention entered into force on 25 March 1998. It has been ratified by Belgium, Denmark, Finland, France, Germany, Iceland, Ireland, Luxembourg, Netherlands, Norway, Portugal, Sweden, Switzerland and the United Kingdom and approved by the European Community and Spain.

Convention OSPAR

La Convention pour la protection du milieu marin de l'Atlantique du Nord-Est, dite Convention OSPAR, a été ouverte à la signature à la réunion ministérielle des anciennes Commissions d'Oslo et de Paris, à Paris le 22 septembre 1992. La Convention est entrée en vigueur le 25 mars 1998. La Convention a été ratifiée par l'Allemagne, la Belgique, le Danemark, la Finlande, la France, l'Irlande, l'Islande, le Luxembourg, la Norvège, les Pays-Bas, le Portugal, le Royaume-Uni de Grande Bretagne et d'Irlande du Nord, la Suède et la Suisse et approuvée par la Communauté européenne et l'Espagne.

Acknowledgement

This report has been prepared by Ivor Rees c/o School of Ocean Sciences, University of Wales, Bangor, UK on behalf of the Joint Nature Conservation Committee (JNCC) for the UK as lead party for *Modiolus modiolus* beds.

Thanks to Roger Coggan, Norbert Dankers, Steven Degraer, Jon Eiriksson, Aurelie Foveau, Sven Funder, John Hartley, Hilmar Hinz, Terry Holt, Haakon Hop, Mike Kendall, Tomas Lundalv, Andy Mackie, Jamie Mair, Geoff Meaden, Julia Nunn, Graham Oliver, Karsten Reise, Heye Rumohr, Stefan Ragnarsson, Bill Sanderson, Liz Sides, Jan Sorensen, Anne Brit Storeng.

Photo acknowledgement:
Cover page: ©Mr Dai Roberts

Contents

Background Document for *Modiolus modiolus* beds

Executive Summary

This background document on *M.modiolus* beds has been developed by OSPAR following the inclusion of this habitat on the OSPAR List of threatened and/or declining species and habitats (OSPAR other agreement 2008-6). The document provides a compilation of the reviews and assessments that have been prepared concerning this habitat since the agreement to include it in the OSPAR List in 2004. The original evaluation used to justify the inclusion of *M.modiolus* beds in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, extent and condition) and key threats prepared during 2008-2009. Chapter 7 provides recommendations for the actions and measures that could be taken to improve the conservation status of the habitat. On the basis of these recommendations, OSPAR will continue its work to ensure the protection of *M.modiolus* beds, where necessary in cooperation with other organisations. This document may be updated to reflect further developments.

Récapitulatif

Le présent document de fond sur les bancs de *M.modiolus* a été élaboré par OSPAR à la suite de l'inclusion de cet habitat dans la liste OSPAR des espèces et habitats menacés et/ou en déclin. Ce document comporte une compilation des revues et des évaluations concernant cet habitat qui ont été préparées depuis qu'il a été convenu de l'inclure dans la Liste OSPAR en 2004. L'évaluation d'origine permettant de justifier l'inclusion des bancs de *M.modiolus* dans la Liste OSPAR est suivie d'une évaluation des informations les plus récentes sur son statut (distribution, étendue, condition) et des menaces clés, préparée en 2008-2009. Le chapitre 7 recommande des actions et mesures à prendre éventuellement afin d'améliorer l'état de conservation de l'habitat OSPAR poursuivra ses travaux, en se fondant sur ces recommandations, afin de s'assurer de la protection des bancs de *M.modiolus*, le cas échéant en coopération avec d'autres organisations. Le présent document pourra être actualisé pour tenir compte de nouvelles avancées.

1. Background Information

Name of habitat

Modiolus modiolus beds

Definition of habitat

The horse mussel *Modiolus modiolus* forms dense beds, at depths up to 70 m (but may extend onto the lower shore), mostly in fully saline conditions and often in tide-swept areas. Although *M.modiolus* is a widespread and common species, horse mussel beds (with typically 30% cover or more) are more limited in their distribution. *M.modiolus* beds are found on a range of substrata, from cobbles through to muddy gravels and sands, where they tend to have a stabilising effect, due to the production of byssal threads. Communities associated with *M.modiolus* beds are diverse, with a wide range of epibiota and infauna being recorded, including hydroids, red seaweeds, solitary ascidians and bivalves such as *Aequipecten opercularis* and *Chlamys varia*. As *M.modiolus* is an Arctic-Boreal species, its distribution ranges from the seas around Scandinavia (including Skagerrak & Kattegat) and Iceland south to the Bay of Biscay.

Correlation with habitat classification schemes

The OSPAR priority habitat type includes four *M.modiolus* bed habitat types, as defined in both the European EUNIS habitat classification (2007 version; http://eunis.eea.europa.eu/habitats.jsp) and the National Marine Habitat Classification for Britain and Ireland (Connor *et al*., 2004). These are:

- EUNIS Code: A5.621, A5.622, A5.623 and A5.624
- National Marine Habitat Classification for UK & Ireland code: SS.SBR.SMus.ModT, SS.SBR.SMus.ModMx, SS.SBR.SMus.ModHAs and SS.SBR.SMus.ModCvar

The EUNIS classification descriptions are derived largely from records of associated epibiota in UK waters. Revisions may be needed to account for different species occurring amongst *M.modiolus* beds in northerly biogeographic regions (*e.g.* Iceland, Finmark Coast and White Sea).

A topographic classification could also be useful for describing features of the beds, bearing in mind that extensive surveys of beds will rely more on sonar methods supplemented by visual recording to provide ground-truth information. For example, the mussels can be in isolated clumps, in ribbon-like reefs with superimposed wave-like undulations or in sheets.

Common characteristics of the habitat

M.modiolus forms “beds” (biogenic reefs) on the seabed where dense populations of these large bivalves occur (Holt, *et al*, 1998). Individuals can grow to lengths >150 mm and can live for >45 years (Anwar, *et al,* 1990). The mussels attach to the substratum and to each other with byssal threads so that they aggregate into clumps. They can cover much of the underlying seabed to create a distinctive biogenic habitat. Gradations occur from isolated individuals, which may nest in the sediment, through well-scattered small clumps to near total coverage of the seabed. Patches extending over >10 m^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 <u>not</u> classified here as “beds”.

M.modiolus is a widespread and common Pan-Boreal species (Tebble, 1966; Poppe & Goto, 1993), but “beds” are much more limited in their distribution becoming absent or scarce towards the geographic range limits of the species. The aggregations of *M.modiolus* which form beds typically occur at depths from the lower shore (Davenport & Kjorsvik, 1982) to about 70 m but clumps of them have been found below 100 m in the Irish Sea. Off the Faeroes they occur to about 200m depth, being densest at 65-95 m (Tendal & Dinesen, 2005). Mostly the beds are in current-swept fully-saline locations, although some can be found in sheltered bays, fjords or lochs, with some beds restricted to depths below haloclines. *Modiolus* beds occur on a range of substrata, most often on cobbles through to muddy gravels of glacigenic or glaciomarine origin, but have also been found on bedrock. They can also colonise the legs of offshore structures (Anwar *et al*, 1990). Beds are often persistent features which build up through accumulating faecal pellets, shell and trapped sand, so that they may become de-coupled from the substratum on which they were originally founded. They can be self-sustaining to the extent that spat survival is greatest in the crevices amongst the byssal threads of the mature clumps. Predation by crabs and starfish is high while individuals are small, so the demographic pattern allows for rapid somatic growth for the first few years followed by longevity at slower growth rates. Growth, longevity and maximum sizes vary with environmental stresses in different localities (Anwar *et al*, 1990).

The mussels have a stabilising effect on the seabed, due to binding by the byssal threads; thus beds can alter sea floor roughness, topography and acoustic reflectivity. The composition of the sediment in and under the mussel clumps also differs. Individual *M.modiolus* most often live partly buried in the sediment (Meadows & Shand, 1989). Substantial accumulations of dead shell often occur in and around the long established beds. Associated with *M.modiolus* beds are diverse ranges of epibiota attached to the mussels and to the stabilised gravel. Foliose and encrusting calcareous red algae grow on them where parts of the beds are within photic depths. In the shallow sublittoral zone they may provide attachment for kelp. The relative proportions of soft epibiota (sponges, hydroids and soft corals) compared to hard epibiota (serpulid polychaetes, barnacles and saddle oysters) varies. These differences are mainly due to current stress acting through abrasion by sand and shell fragments carried as bed load. Infauna, supported through pelagic-benthic coupling by these filter feeders (Navarro & Thompson, 1997; Wildish & Fader, 1998), is enhanced and there are niches for higher numbers of crevice-living species, predators and scavengers (Rees, *et al,* 2008). Fish make use of both the higher production of benthic prey and the added structural complexity. Several commercially exploited scallop species *(Pecten maximus*, *Aequipecten opercularis* and *Chlamys islandica*) occur in the same habitat and may as spat have been attached to the hydroids growing on the mussels.

2. Original evaluation against the Texel-Faial selection criteria

OSPAR Regions and biogeographic zones where the habitat occurs

The OSPAR List recognises that M. Modiolus beds occur in all OSPAR Regions. There is good evidence of the occurrence of *M.modiolus* beds in OSPAR Regions I, II, III, but the records in Region IV need confirmation. There is no evidence to suggest the feature occurs in Region V.

By Dinter (2001) biogeographic zones, *Modiolus* beds are found in:-

Barents Sea (southern parts)

White Sea

Finmark Coast

Norwegian Coast – W. Norway

Norwegian Coast - Skaggerak

South Iceland – Faeroe Shelf

Boreal

Boreal-Lusitanean (far northern part)

OSPAR Regions and biogeographic zones where the habitat is under threat and/or in decline

The OSPAR List recognises that M. Modiolus beds are under threat and/or decline in all Regions where they occur. The scale of threats and the strength of available evidence varies between regions and the waters of Contracting Parties.

M.modiolus beds are vulnerable in most of the Dinter biogeographic zones where they currently occur, but evidence for decline is insufficient in some zones.

Evaluation against the Texel-Faial criteria for which the habitat was put on the OSPAR List

The nomination of *M.modiolus* beds to be placed on the OSPAR List was on the basis of an evaluation of their status according to the Texel-Faial Criteria (OSPAR 2003). The citation noted the sensitivity, particularly to physical disturbance, of this biogenic habitat and its low resilience which results from the long life span of individuals coupled with erratic recruitment, that is most successful amongst pre-existing beds. The citation also noted ecological significance of the biogenic habitat and evidence for significant declines or degradation at several locations where there have been detailed studies.

See Annex 3 for a detailed evaluation against the Texel-Faial criteria.

3. Current status of the habitat

Distribution in OSPAR Region

M.modiolus beds occur patchily and mainly in cold temperate coastal parts of the north-east Atlantic shelf seas, from southern parts of the Barents Sea and the White Sea to the southern North Sea and the southern Irish Sea. Beds also occur around the Atlantic islands of Iceland and the Faeroes. The species is currently absent in Arctic waters at Svalbard and East Greenland although it did occur at Svalbard during the Holocene climate optimum 8700-7700 BP (Salvigsen *et al,* 2007). The southern end of the biogeographic range of *M.modiolus* extends at least to the Bay of Biscay (Poppe & Goto, 1993) but it is not known to form beds beyond the North Sea and the southern Irish Sea. At the south of its range *M.modiolus* overlaps with *M.adriaticus;* the later species does not seem to aggregate to form beds.

The currently available data on distribution of the habitat in the OSPAR area (Figure 1) and the UK (Figure 2) does not fully concur with recent information from experts. The discrepancies are partly due to difficulties in distinguishing records of individual specimens from aggregations which are sufficient to be reliably classified as beds. An overview of distribution in the waters of OSPAR Contracting Parties and the Russian part of the OSPAR Area is provided in Annex I.

Habitat extent and environmental factors

The total extent of *M.modiolus s* beds in the OSPAR area is unknown. Indeed there is relatively limited information on habitat extent within Contracting Parties, although this is improving (e.g. through the Mapping European Seabed Habitats Programme).

Individual *M.modiolus* beds usually extend over only a few square kilometres and often the area of a bed measures only a few hectares or less. Several semi-discrete beds may occur within a limited area. Some of the beds have sufficiently distinct borders, which show up using acoustic survey methods, so their extent can be measured accurately (Lindenbaum, *et al*, 2008). In other cases there are gradations from obvious biogenic reef, to patchy ribbons, to areas with frequent substantial clumps and then to sparsely-distributed small clumps. Beds that may have once had discrete edges will often show open tracks through them and be degraded to patchy clumps at the margins after disturbance by towed fishing gear. Bed extent is then open to differing interpretations.

Beds have been found in a wide range of situations from the lower shore to nearly 200 m depth and on a wide range of substrata from bed rock to cohesive mud. Most commonly they are in full salinity and on mixed coarse sediments of glacial or glacio-marine origin. Environmental conditions associated with particular beds are often localised so it is difficult to define the ecological limits. Local situations include places where currents are stronger over sills at the mouths of fjords or lochs and in channels between islands. Computer-aided prediction, using GIS methods to overlay multiple physical and chemical factors, has been fairly successful for predicting sediment habitats. However, forecasting precisely where particular biogenic reefs should occur is less practicable due to the complex of biological feedback loops involved. Some *Modiolus* beds have probably existed at or near the same locations for so long that they may have originally developed when environmental conditions were different from today and might be regarded as relicts. In situations where isostatic rebound has altered depths and local current flows, beds may persist in sub-optimal conditions.

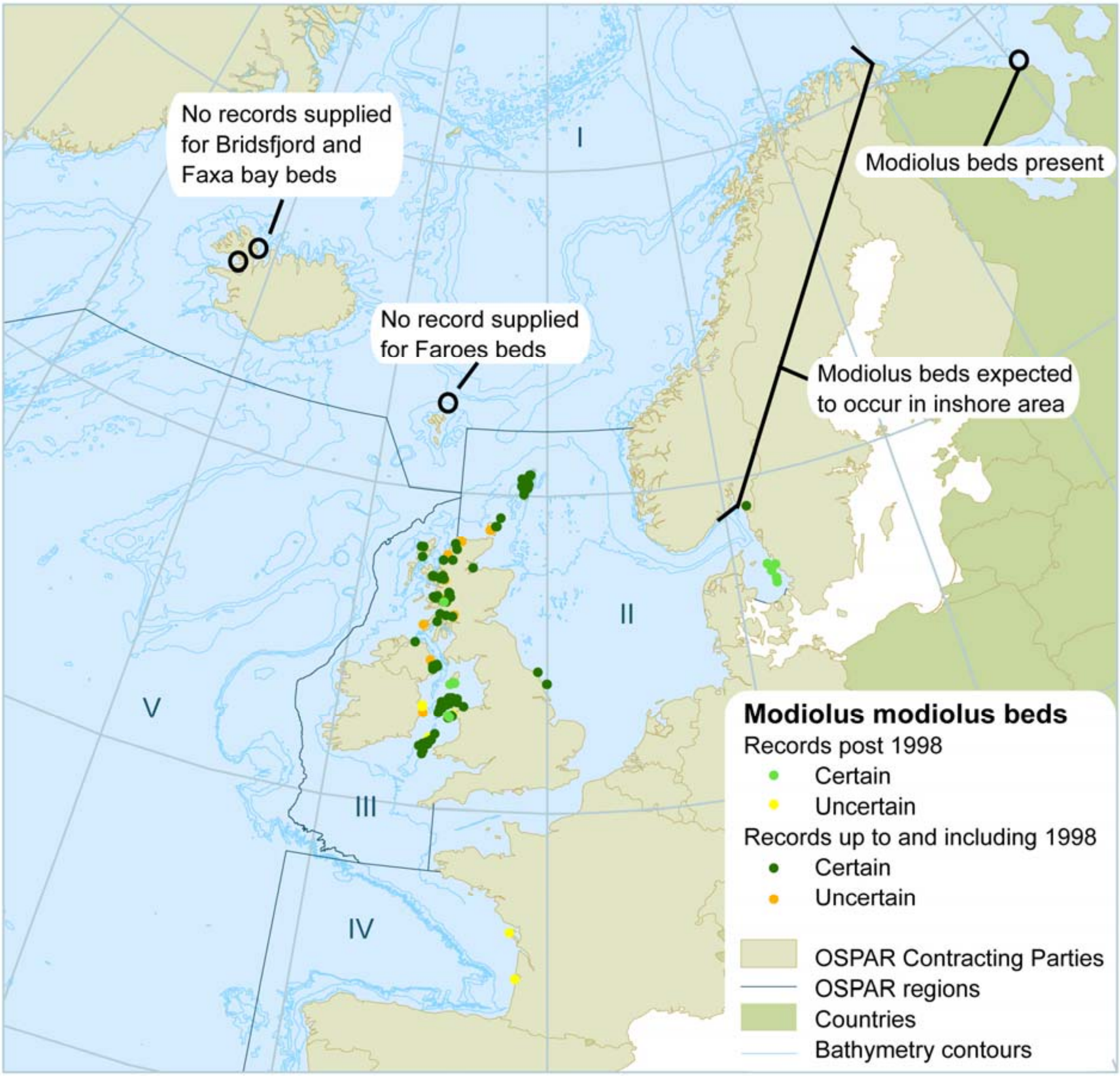

Figure 1. Distribution of *M.modiolus*beds in the OSPAR area, based on data supplied by Contracting Parties to December 2008 (annotations by Ivor Rees, September 2008, updated in January 2010).

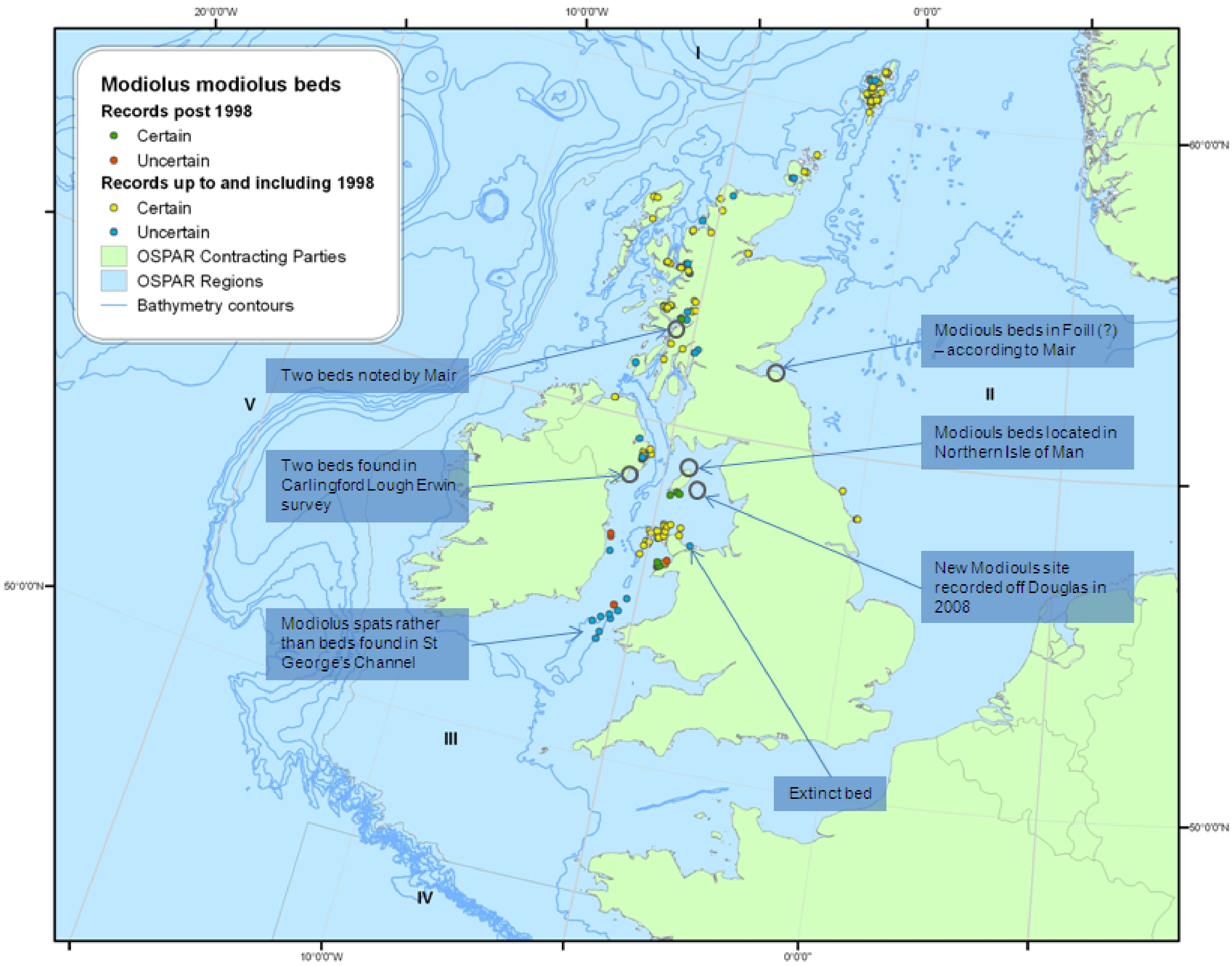

Figure 2. Distribution of *M.modiolus* beds in UK waters, based on data supplied by Contracting Parties to December 2008 (annotations by Ivor Rees, September 2008, updated by JNCC January 2009).[1]

Condition (current/trends/future prospects)

The condition of *Modiolus* beds may be judged in several different ways:

- Spatial integrity, such as whether fishing gear tracks cut across a bed.
- Topographic integrity, such as the continued presence of ridges, mounds and other biogenic relief.
- Size distributions of the mussels and whether the populations are being adequately renewed by successful spat settlement and juvenile survival through the first years when they are most vulnerable to predation.
- Abundance, composition, condition and diversity of the associated biota. For physical disturbance impacts, changes in soft epifauna are more likely. Some of the vagile epifauna, such as brittlestars (*e.g. Ophiothrix fragilis*) are known to fluctuate markedly in abundance, so caution is needed when interpreting change. Damage also leads to increased abundance of scavengers, which are attracted to disturbed areas.

[1] The coastline and bathymetry are derived from the GEBCO digital atlas. The map is projected in the North Pole Lambert Azimuthal Equal Area projection (Central Meridian 0.000000, Latitude of origin 90.000000).

Only a few *M.modiolus* beds are known have been surveyed over long enough time spans for evidence of change to be apparent. In the Irish Sea, south of the Isle of Man, an extensive bed was almost completely lost due to scallop dredging (Veale *et al*, 2000). For similar reasons, beds in Strangford Lough (Northern Ireland) also showed severe declines (Service & Magorrian 1997). Recently beds in North Anglesey (Wales) have been destroyed by fishing activity (Holt 2008, Countryside Council for Wales, *pers. comm*.). By contrast, in an Icelandic bay *M.modiolus* was still the dominant by-catch species in scallop dredges 30 years after scallop dredging began (Garcia & Ragnarsson, 2007). In Sullom Voe (Shetland) a bed coincident with a pipeline showed signs of recovery, with some re-colonisation of disturbed sediment after a few years (Mair *et al*, 2000). A substantial population was present 10 years after installation on the legs of an oil platform in the North Sea, but in this situation the young mussels would have been free of much predation (Anwar *et al*, 1990). As a species it appears to have declined in the North Sea. Comparing occurrences by ICES Rectangles Callaway et al (2007) showed that the species had been found in the 1982 - 85 period in 11 rectangles, but comparable international surveys in 2000 found it in only 1 rectangle.

Over large parts of the geographic range of this habitat there is at present too little evidence to determine the scale of anthropogenic impacts. There is clear evidence of fishing impacts and anecdotal evidence for declines in quality in the Kattegat. Forecasts of change to 2020 depend most on developments in fisheries management, including the emphasis given to ecosystem-based management. Gear technology and navigation precision improvements will have influences as will relationships between fuel costs and landed values. In places, trends will also depend on incentives for investment in renewable energy infrastructure offshore, particularly for tidal power. In the longer term it is likely that climate change will reduce beds in the south but permit expansion in the far north (Hiscock *et al*, 2004). Owing to the long life-span of these molluscs and the apparent persistence of established beds there will be a considerable time-lag between climate shift and observable habitat changes. At present it is not possible to confidently discriminate climate change declines against a background of fishing impacts. Failures of recruitment or of the survival of young mussels through the period when they are most vulnerable to predation are the most likely ways change will come about in the south. Having shown an ability to colonise artificial habitats offshore, it is likely that where suitable habitat exist, the species will be able to spread further in the Arctic.

Limitations in knowledge

Partly as result of the patchy distribution of this biogenic habitat and uncertainty whether records refer to individuals or beds, detailed up-to-date information on distribution is lacking over significant parts of the range. Without such information it is not possible to provide estimates of the area covered by the *M.modiolus* bed habitat or the proportion it makes up of the shelf seas in the whole OSPAR area.

The full range of variation in *M.modiolus* biotopes is poorly documented, but it is certainly wider than implied by the present EUNIS classification. Differences in the sensitivity to various perturbations are not known.

Bearing in mind the longevity of the mussels and the small number of studies running long enough to detect change, inferences often have to be drawn by reference to earlier sampling for different purposes, where different sampling gears were used and positions were less accurately known.

4. Evaluation of threats and impacts

A summary of the key activities which can cause impacts to *M.modiolus* beds is given in Table 1.

Table 1. Summary of key threats and impacts to *M.modiolus* beds

Type of impact	Cause of threat	Comment	Scale of threat
Destruction or degradation through extensive physical impacts	Dredge fisheries for scallops, beam and otter trawling	A previously substantial bed south of the Isle of Man was eliminated by intensive dredging for scallops in the 1970s and 1980s. In Strangford Lough Northern Ireland beds that used to cover extensive areas were reduced to isolated small clumps by trawling for scallops. With other biogenic features beds are damaged by towed fishing (Jennings & Kaiser, 1998).	Very High
Habitat loss or degradation through site specific physical damage	Infrastructure development (dam construction, coastal development, oil & gas exploitation)	Infrastructure developments such as oil platform installation, temporary placing of exploratory rigs, burial of pipelines and cables all cause local impacts. Other site specific developments such as tidal energy barrages or major port dredging could have wider effects but would be subject to EIA.	Medium - Low
Pollution: terrestrial run-off or organic overload	Agriculture, forestry and aquaculture. Dumping at sea of dredge spoil, pipe discharges of effluent or cooling water	Potential effects where enclosed water bodies suffer temporary hypoxia in bottom waters. Local effects around licensed dumping grounds, some wrecks, and effluent pipes. Effects of discharges are often mitigated by EIA and controls.	Low and local
Removal of species (mussels)	Harvesting of mussels	Take for both human consumption and bait is thought to be small. Some *M. Modiolus* beds can have *Mytilus edulis* seed settling on them and may have been affected by dredging the seed for mussel cultivation.	Low and local
Non-native species	Introductions for aquaculture or inadvertently	Possible effects from the spread of the King Crab *Paralithodes* which was transferred by Russia from the Pacific have been suggested (Jorgensen, 2005) but not studied in detail. Potential always exists for non-native species introduced for aquaculture to bring with them diseases or pests that cause significant impacts, although regulation reduces risks in most countries bordering the north-east Atlantic. Accidental introductions by shipping are frequent but to date no species has been reported as significantly affecting *Modiolus* beds.	Uncertain

5. Existing management measures

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.

Areas closed to particular types of fishing can be used to protect certain sensitive habitats and species. They could be applied more widely to protect the *M.modiolus* bed habitat. Conflicts between fishing fleets using towed and static gear methods can also be reduced by this type of restrictive zoning. Static gears (long-lines, set nets and traps) have comparatively little impact on the fundamental structure of *M.modiolus* beds so there can be conservation and ecosystem benefits from local zoning. However, where the rotational closures have been proposed for some scallop fisheries, these would probably not conserve *M.modiolus* beds, because recovery times are far too long. Seasonal closures would be even less effective. Such matters fall primarily within the remit of fisheries organisations but OSPAR can offer opinions especially where ecosystem-based fisheries management interfaces with the OSPAR remit on species and habitat protection.

Data on the intensity of fishing, both spatially and by gear types are based on log book returns, on patrol vessel or aircraft surveillance and increasingly on GPS linked Vessel Monitoring Systems (VMS). The latter report vessel positions to national authorities via satellite links. Compliance with area closures and some other management measures depends partly on such records. There are particular problems in reliance on VMS to monitor the coincidence of scallop dredgers with *M.modiolus* beds. Some dredging is done by vessels below the size where VMS is mandatory. More importantly, VMS only logs vessel positions at regularly-spaced intervals, but *M.modiolus* beds tend to occur patchily at much smaller scales than the distances vessels can tow between positions being recorded. Unless buffer zones around protected areas for *M.modiolus* beds are large, it is possible for a vessel to significantly infringe on a feature and go clear again during the interval between positions being recorded. To aid compliance this weakness could be overcome by introducing some extra position recording at randomised unpredictable intervals. Where limited numbers of vessels are licensed to dredge near protected habitats in some coastal waters, mobile telephone rather than satellite links could permit positions to be logged more frequently at lower cost. Alternatively the more precise “black box” recording systems used to manage aggregate dredging could be adapted.

Requirements for Impact Assessments and or habitat surveys when major infrastructure developments are planned will often serve to make extra information available on the location and extent of any biogenic reefs. Sometimes pipeline or cable routes can then be chosen to avoid particularly sensitive features. Environmental monitoring of major infrastructure developments has often helped provide long-term data not easily obtained by other means, particularly on the re-colonisation of disturbed areas.

6. Conclusion on overall status

As *M.modiolus* can be found living individually in benthic habitats, as well as forming aggregations, where it is the key species structuring a biogenic habitat. Defining what should be classified as *M.modiolus* bed is seldom absolute. The beds tend to occur as quite small features that are often patchy. It is difficult to predict precisely where beds occur, to define the limits of particular beds or to measure the extent of the habitat. While some beds are well known, even in areas where the distribution of coarse-scale benthic habitats is well understood, previously unknown small beds of *M. Modiolus* continue to be found. Although several maps have been produced both for countries and regions, there are considerable uncertainties over the current distribution of the habitat. In particular, some maps have shown stations as beds where only spat-sized mussels were found in grab samples. Some Contracting Parties have surveys in progress, using multi-beam acoustic techniques, to derive habitat maps of the whole of their waters, while others are undertaking targeted surveys of sensitive habitats. At the present time it is thus premature to put much reliance on sea area scale maps of the *M.modiolus* bed habitat. However, since they can often be detected by combinations of the sonar and remote camera methods that are now routinely employed, it is anticipated that better information will be available within 5 years.

As ecological features there is good evidence that:

- *M.modiolus* beds have a role in benthic productivity which is disproportionate to their extent, have high biodiversity and may be locally important in providing both refugia and feeding opportunities for young fish.
- Although individual large mussels are relatively resistant to mechanical damage, disturbance to bed structures and breakages by heavy fishing gear is the most significant anthropogenic threat to these features. Repeated disturbance can eliminate beds entirely.

Nomination of *M.modiolus* beds to be placed on the OSPAR List was on the basis of an evaluation of their status according to the Texel-Faial Criteria (OSPAR other agreement 2003-13). The citation noted the sensitivity, particularly to physical disturbance, of this biogenic habitat and its low resilience. This results from the long life span of individual mussels, coupled with erratic recruitment and that spat survival is most successful amongst pre-existing beds. The ecological significance of the biogenic habitat and evidence for significant declines or degradation at several locations has been documented. Table 2 provides an updated evaluation. The main threats to this habitat are activities that physically disturb the seabed, such as demersal fisheries for scallops, marine pollution through eutrophication and at the southern limits, increased bottom water temperature due to climate change.

Table 2: Summary assessment of *M.modiolus* beds against the Texel-Faial criteria.

Criterion	Comments	Evaluation
Global importance	Outside the OSPAR region, similar biotopes occur in the North West Atlantic (notably in the Bay of Fundy and Gulf of Maine). South of the OSPAR boundary in the Kattegat there are a few beds in more saline parts of the Belt Seas at the entrance to the Baltic Sea. Beyond the eastern OSPAR limit in the Russian Arctic data are insufficient. Horse mussels occur on both sides of the North Pacific. *M.kurilensis* is now considered indistinguishable from *M.modiolus* (Coan *et al,* 2000).	Qualifies Significant proportion of global extent is in OSPAR area
Regional importance	Given the patchy distribution of *M.modiolus* beds none of the three OSPAR regions, where it occurs, has >75% of the habitat, but amongst the Contracting Parties Norway probably has the greatest extent of this habitat type.	Does not qualify
Rarity	There are significant gaps in available data on the detailed distribution of a habitat that is naturally patchy. Available evidence indicates that fully developed “beds” where the mussels cover most of the sea floor and build up biogenic reefs are **scarce.** They are mainly confined to coastal areas with particular combinations of mixed glacigenic sediments and moderately strong currents. Available evidence suggests that *M.modiolus* beds cover <1% of the sea areas of all Contracting Parties.	Qualifies
Ecological significance	*M.modiolus* beds are relatively scarce features of limited and patchy extent. Their ecological significance is disproportionate to the areas they cover: 1. Biogenic morphological features vulnerable to degradation or flattening by towed fishing gear. 2. Areas of higher biodiversity than the surrounding sea floor by providing stable substrata for epibiota and reduced abrasion from bed load particles. Increased structural heterogeneity also enhances biodiversity. 3. Localities with increased benthic production due to the filter feeding of the mussels which enhances pelagic-benthic coupling. There are effects at trophic levels through to top predators. 4. Structured biogenic reef habitats that are favoured by juvenile fish due to	Qualifies

Criterion	Comments	Evaluation
	local current velocity alteration, feeding opportunities and sometimes by providing refugia from larger predators. 5. Scallop spat settle on the hydroids and other biota growing on the mussels or stabilised sediment.	
Decline	Although too few individual beds have been mapped or studied in detail over decadal time periods to confirm declines throughout the range, available evidence indicates severe declines where there has been intensive fishing for scallops.	Qualifies locally and potentially more widely as new information becomes available
Sensitivity	The findings from various studies on the dynamics and sensitivity of this habitat were brought together in a review by Holt *et al,* (1998). ***Mechanical damage by fishing:*** Towed fishing gear and especially scallop dredges and heavy beam trawls tears up the mussel clumps. A proportion of the mussels are smashed and even if they survive to be dumped back, the structural integrity of the biogenic reef will have been disrupted and the ecosystem degraded through damage to the associated soft biota. Scavenging species are attracted to the damaged areas. By breaking into the reef it may be subject to erosion or to greater abrasion from sand and shell no longer stabilised by the byssal bound mass. Even a single pass by such gear causes degradation and repeated fishing episodes result in beds with nearly full coverage by mussels and complex biogenic topography being changed to a residue of small clumps of living mussels amongst masses of dead shells. Sometimes nearly all traces of a former bed are lost. Fishing gear impacts rate most highly because (a) the activity is extensive and (b) some of the target species often occur amongst the mussel beds, ***Mechanical damage by infrastructure developments:*** Localised disturbance can be caused to *M.modiolus* beds by a wide range of infrastructure developments such as the burial of pipelines or cables, the emplacement of oil and gas rigs and renewable energy structures. Dredging of shipping channels, dumping at sea and anchoring can all cause physical damage at site specific scales. ***Biological events:*** A few *M.modiolus* beds in fjord and sea loch situations may be vulnerable to intermittent hypoxia events brought on by the collapse of plankton blooms caused by eutrophication or the waste products from fish farms. There is potential for non-native species such as the king crab *Paralithodes* to have an impact, but these are more likely to have greater influences on the associated epibiota than on the mussels themselves. ***Physico-chemical events:*** Extreme weather events such as storm waves triggering the movement of sand wave fields or excessive freshwater run-off into semi-enclosed basins can have local effects. Climate change is forecast to inhibit recruitment at the southern limits while permitting colonisation of parts of the Arctic, such as Svalbard, where the species is known from sub-fossil material to have occurred during a period in the early Holocene when sea temperatures were higher. There are locations suitable for long-term expansion in the north to balance losses in the south.	Qualifies – rated as Very Sensitive

7. What action should be taken at an OSPAR level?

Habitat survey and mapping: Contracting Parties should be encouraged to complete habitat surveys of their sea areas. Where multibeam surveys are being undertaken primarily for hydrographic mapping or exploited resource assessment, more emphasis needs to be put on deriving habitat maps as well. Since larger swathes can be covered in deeper water and since the topography of the deeper areas was less well known from navigation surveys, there has been a tendency to try to cover deeper parts of EEZs first, for example by Iceland and Ireland. Attention also needs to be directed towards closer links between hydrographic surveying and habitat mapping in coastal waters. Where sensitive and biogenic habitats are concerned, benthic terrain models using digital survey bathymetry can help narrow areas of search. While physically controlled biotopes can be predicted from oceanographic and sediment parameters, methods are not yet adequate to reliably predict where *M.modiolus* bed habitats will occur, so there is a greater need for actual biological and targeted sonar mapping surveys. Quite detailed habitat mapping is needed both to aid the conservation of *M.modiolus* beds and for ecosystem-based fishery management to take account of these sensitive features.

Communication: OSPAR should ask the EU and other fishery management authorities to review the effectiveness of VMS for monitoring compliance with closures of small areas of sensitive habitat.

Adapt the habitat definition: Recognizing that at present the parts of the EUNIS classification concerned with *M.modiolus* beds do not cover the full spectrum of *M.modiolus* biotopes and their descriptions, these parts of the classification should be revised. The present categories are based largely on UK data from near the southern end of the range of this habitat, so more account needs to be taken of the variants found in the north of the OSPAR area. Some revision in the classification to take more account of biogenic bedforms would help as sonar methods are likely to play a major role in the mapping and assessment of *M.modiolus* beds in the future.

Improve assessment: There is not enough data to assess the overall extent of *M.modiolus* beds in the OSPAR area or the condition of the beds. Consideration should be given to bringing together a specialist working group drawn from scientists experienced in this particular habitat and from the range of Contracting Parties with significant amounts of the habitat. The remit should primarily be to provide a more complete assessment of bed distribution and to advise on future monitoring including survey and sampling methods.

Assess measures: assess whether existing management measures for the protection of *M.modiolus* beds are effective, and what further measures, if any, might be needed to assess the key threats.

Targeted MPA designation and management: recommend that Contracting Parties intensify their work to identify, select and effectively manage sites where *M.modiolus* beds are known to exist as OSPAR Marine Protected Areas and to ensure management plans for existing protected sites (*e.g.* SACs) are not leading to further deterioration of the habitat.

Reporting on national actions: OSPAR should request that Contracting Parties report back to the OSPAR Commission on the implementation of the above recommendations, so that the development of the necessary measures can be evaluated. As a first step Contracting Parties whose EEZ contains the habitat should make an assessment of the effectiveness of the regulations they already have in place for its protection, consider how those regulations might be made more effective through improved monitoring, control and surveillance and report the results to the OSPAR Commission (through periodic reporting).

Annex 1: Overview of data and information by Contracting Party sea areas

The information presented here is based partly on literature sources, partly on data supplied by the Contracting Parties and particularly from contacts with individual scientists who have published on the benthos of relevant parts of the OSPAR region. The areas mentioned here do not distinguish between Territorial Waters and Exclusive Economic Zones.

Belgium: This bivalve is a rare / scarce species in the Belgian sector of the southern North Sea (Degraer *et al*, 2005). The sector has mainly sandy seabed where dense *M.modiolus* populations would not be expected.

Denmark: By separate biogeographic regions or having separate administrations:

- The *M.modiolus* community was described a century ago from the **Skagerrak / Kattegat** region by Petersen (1913). The habitat is still known to occur in some of the locations in which it was then documented. A salinity plume front off Cape Skagen in the Kattegat, caused by the low salinity outflow from the Baltic, restricts occurrences further south to depths below a halocline at about 15 m (Josefson & Conley, 1997). Beds are or were also present in some of the complex of channels through the Danish islands at the entrance to the Baltic (*i.e.* just south of the boundary between the OSPAR and HELCOM regions).
- The Danish sector of the **North Sea** has no known *M.modiolus* beds.
- **Faeroe Islands**. *M.modiolus* has been found (Sparck, 1929; Tendal & Dinesen, 2005; Dinesen & Ockelmann, 2005) in abundances which imply the presence of frequent beds. Some definite beds, confirmed by seabed photographs are known, particularly in the channels (sounds) between the islands and to over 200 m depth on parts of the Faeroes Bank. The large barnacle *Chirona* (*Balanus*) *hameri* occurs on *M.modiolus* beds in the Faeroes. Stocks are exploited for human consumption to a limited extent and this mussel species is served in local restaurants.
- **East Greenland**. *M.modiolus* is not known to occur around Greenland at present. Dated shells show that even in the mid Holocene warm period they were only on the west (Davis Strait) side.

France: Nearly all the waters of metropolitan France are in the Lusitanean-Boreal and Boreal-Lusitanean biogeographic regions. French waters are beyond the southern limit where *M.modiolus* is expected to form dense beds, although individual bivalves are recorded in the English Channel and south to the Bay of Biscay. The Dinter (2001) Boreal zone extends as far west in the English Channel as the Contentin Peninsula and there is conflicting information on the status of *M.modiolus* in the Dover Strait. A *M.modiolus* biotope was reported, apparently on the basis of modest numbers of individuals in a few grab samples (Carpentier *et al*, 2004) with part of the roughly mapped biotope being on the UK side of the median line. More intensive mapping of habitats using multibeam sonar and video did not find any *M.modiolus* beds on the UK side of the Strait, so in the absence of more supporting evidence the records are considered to refer to scattered individuals not beds.

Germany: No beds are currently known in the German sector of the North Sea, though there are some areas of coarse mixed ground off Helgoland which might be suitable for the species.

Iceland: Reports from studies of the impacts of scallop dredging in Breidafjordur on the west side of Iceland showed that *M.modiolus* was the most abundant by-catch species (Garcia & Ragnarsson, 2007). The quantities picked up by the dredges indicated that even after about 30 years of quite intensive fishing *M.modiolus* was still abundant and implying that there were beds here. Photographic studies showing the associated fauna have been made (Ragnarrson, *pers. com*,). The present condition of the beds is not fully known. A much earlier benthic study of Faxa Bay (Einarsson, 1941), also on the west coast, detected *M.modiolus* in quantities implying the existence of beds. Sparck (1929) reported *M.modiolus* as abundant. No information has been made available on areas off the north and east coasts which are in colder waters. Iceland is undertaking multi-beam surveys of its EEZ. As this started by concentrating on deeper waters further offshore, data relating to areas likely to support *M.modiolus* beds are not yet available.

Ireland: The only known bed fully in Irish waters was a small one found off Arklow in the southern Irish Sea in 1997 (Wilson *et al*, 2001) but subsequent surveys in the same general area failed to find any more. A bed was also known on the boundary with Northern Ireland (UK) at the mouth of Carlingford Lough (Erwin *et al*, 1990). Some of the grab survey information from central parts of the southern Irish Sea has been misinterpreted as indicating *M.modiolus* beds from numbers of individuals shown in databases, rather than original survey notes or seabed photographs from the same surveys. Grabs here collected only small or spat-sized individuals. The south and west coasts of Ireland are in the Boreal-Lusitanian biogeographic region and although the species has been recorded sparsely no beds are known here or off the north coast to the west of the border with Northern Ireland (Julia Nunn, Ulster Museum, *pers. com*).

Norway: Norway has a comprehensive benthic habitats survey in progress which will record *M.modiolus* beds (MAREANO project). Beds are known to occur at many places along the long and much dissected coast from the Oslofjord to the Finmark coast and the border with the Murmansk coast of Russia. With a new survey in progress it is premature to try to indicate any detail. However it is probable that Norway has more extent of *M.modiolus* beds than any other Contracting Party. Whether previous offshore species records indicate the presence of true *M.modiolus* beds needs to be confirmed.

Portugal: Beyond the southern limit where *M.modiolus* beds form.

Spain: Beyond the southern limit where *M.modiolus* beds form.

Sweden: A small number of *M.modiolus* beds occur on the Swedish west coast fronting the Kattegat. There are some indications of degradation of the associated fauna due to eutrophication.

United Kingdom: Due to devolution and historical administrative arrangements the seas around the UK are considered here by several divisions. For convenience offshore areas are dealt with alongside the adjacent coasts without distinction between territorial waters and the EEZ.

- **England.** A few beds are known on the east coast such as on rough ground off the Humber and the Farne Islands. Some may possibly exist off north Norfolk, as *M.modiolus* was collected here for comparison of trace metals with those from more polluted locations (Richardson, *et al*, 2001). In the Dover Strait (see France) there is conflicting evidence. In the Bristol Channel earlier reference to *M.modiolus* communities is now believed to refer to an abundance of spat-sized individuals and not true beds. Both *M.modiolus* and *M.adriaticus* were found here recently (Mackie *et al*, 2006). No substantial beds are known off the English section of Irish Sea coasts except for one in a channel in the Solway Firth on the border with Scotland (Mair *et al*, 2000).
- **Wales.** A particularly well-studied bed is present off the north side of the Lleyn Peninsula in Caernarfon Bay (Lindenbaum *et al*, 2008; Sanderson *et al*, 2008; Rees *et al*, 2008). Elsewhere in the tide-swept areas around the north-west and north of Anglesey there are a number of small separate beds (Rees, 2005). Some of these have a well-developed epifauna

on the mussels including colonies of *Alcyonium digitatum* and resemble the Lleyn biotope. In more small patches the mussels and the epifauna are subject to significant abrasion by sand or shell fragments. Here the epifauna is restricted to barnacles (*Balanus balanus* and *B.crenatus*) and other hard-shelled taxa. There has been misinterpretation of grab sample records from further south in St Georges Channel, where there were numbers of *Modiolus* spat but no evidence of true beds.

- **Scotland**. The status of *Modiolus* beds around Scotland was reviewed by Mair *et al*. (2000) who noted that the Marine Nature Conservation Review data set (held by JNCC) had 67 records of beds. A considerable number of beds are known from the west coast sealochs, particularly in locations where currents are accelerated through narrow channels. Beds are frequent in both the Orkney and the Shetland islands. Some of these are in the voes and some in the channels between islands. In contrast, few beds were known from the east coast. Fragments of *M.modiolus* shell were recorded during sediment surveys on Rockall Bank (Scoffin *et al*, 1980) but beds were not known there.

- **Northern Ireland** The distribution here is largely known from an extensive sublittoral diving survey (Erwin *et al*, 1990). Beds were reported from off the north coast and the east coast as well as in several loughs. The beds in Strangford Lough have been subject to many studies over the last 25 years (Brown, 1984; Brown & Seed, 1977). Studies were both on the fundamental biology of the mussels and the effects of disturbance in a Special Area of Conservation (Service & Magorrian, 1997). Proceedings over failure to abide by the Habitats Directive stimulated further monitoring (Roberts *et al*, 2004). Much of the former semi-continuous bed here has been reduced to a few patchy clumps. Small areas resembling the original bed are limited to locations between rocks that could not be fished.

- **Isle of Man**. Around the island beds occurred mainly in two areas off the southern and northern ends of the island. The extent of the southern bed, which stretched in an arc from off Langness towards the Calf was estimated by Jones (1951). This bed was notable for the substantial population of the large barnacle *Chirona* (*Balanus*) *hameri* growing on it. The bed was known to be present in the late 1960s but by the 1980s it had almost totally disappeared. This was attributed to intensive fishing for the scallop *Pecten maximus* (Hill *et al*, 1999; Veale *et al*, 2000). An uncommon form of *M.modiolus* bed occurs off the north end of the Isle of Man. Here, in strong tides, the mussels bind together glacial cobbles and gravel, forming waves that show on side-scan and multi-beam records (Holt *et al*, 1998). Unlike beds in less tide-swept situations, the mussels live almost totally embedded in the substratum. Another small bed was recently found off Douglas in a location where it would have escaped fishing disturbance owing to bedrock outcrops. A survey of seabed habitats round the Isle of Man is currently being undertaken in anticipation of ecosystem-based fishery management measures.

- **Channel Islands**. No beds known.

Russia (not an OSPAR Contracting Party, but with observer status in OSPAR)

The OSPAR area extends across Russian waters in the Barents Sea, the Murmansk coast and the White Sea. *M.modiolus*-dominated communities have been described (Denisenko *et al*, 2007) but information on the extent was not available. A form of community characterised by *M.modiolus* and *Verruca* has been described.

Annex 2: Detailed description of the proposed monitoring and assessment strategies

Monitoring the status and condition of *M.modiolus* beds by Contracting Parties will require drawing together:

- Information on the presence of beds and their locations including changes in geographic range.
- Estimates of the overall extent of beds by the relevant Contracting Parties.
- Surveys at intervals to monitor the extent and integrity of selected beds of a range of types and throughout the geographical range. A re-survey interval of 6 years is suggested, unless specific damaging activities are known to have occurred.
- Targeted sampling to monitor the age and size frequency distribution of the mussels and whether recruitment has taken place.
- Assessment of the associated epibiota in a selected range of beds by video or diving methods. Assessment of the associated infauna by targeted sampling.
- Monitoring those activities and developments that are likely to be most detrimental to the beds.

Survey and monitoring methods

Sonar

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 often create bedforms that can be seen on sonar records. Thus a range of different types of sonar equipment have been successfully used to locate, survey and monitor *M.modiolus* beds, but they are not effective in all circumstances (Lindenbaum *et al*, 2008).

(A) **Acoustic Ground Discrimination Systems**. In dense populations *M.modiolus* influences the reflectivity of the seabed to sound in two ways. Firstly, because the shells generally lie pointing upwards, sound waves tend to be scattered more than from a flat surface. This is roughly analogous to the cones in an anechoic chamber. So beds of *M.modiolus* will often show as a “softer” seabed than the surrounding areas of sandy gravel and embedded cobbles. The distinction may sometimes be seen on the display from single-beam vertical echo-sounders using frequencies in the 130 – 200 KHz range. It shows particularly in the relative strength of the first multiple echo. This is one of the differences exploited by computerised acoustic ground discrimination systems (AGDS) systems such as RoxAnn. Secondly, because of the uneven surface of the *M.modiolus* bed the return echo is slightly more prolonged and this difference is also exploited by some AGDS (*e.g.* QTC – View) to help distinguish differences in seabed types. The disadvantage of using vertical sounders to survey *M.modiolus* beds is that unless survey lines are very close together, a considerable amount of interpolation is needed when trying to determine boundaries. RoxAnn was used to define the extent of beds in Strangford Lough (Magorrian, 1995), but there were subsequent doubts whether some dead mussels still in life positions may have influenced the records (Roberts, *et al*, 2004). Off North Wales RoxAnn gave broadly similar though less precise estimates of bed extent to later studies by side-scan (Lindenbaum *et al* 2008).

(B) Side-scan Sonar. Particularly if the sonar tow fish can be run relatively close to the bottom (<10 m), the irregularities in the seabed produced by *M.modiolus* reefs / bioherms can be readily distinguished. In moderately strong tidal currents the beds form linear features with semi-regular waves superimposed (Wildish *et al*, 1997; Lindenbaum *et al*, 2008). With experience, the irregular waves produced by the mussel bed can be distinguished from more regular sedimentary bedforms. The boundaries of a *M.modiolus* bed may show clearly, thus allowing the bed to be mapped with a degree of accuracy. By this means its extent can be determined using GIS. Side-scan is less effective in mapping beds in areas with low currents that have a more level bed surface or where the bed is reduced to isolated small clumps of the mussels (Nunny, 1990). Ideally sonar lines should be run so that there is nearly 50% overlap to allow comprehensive merging to map a bed. Where the extent of the area to be covered does not permit total coverage it has sometimes been found that running a series of corridors with three overlapping lines and then a gap to the next corridor is the best compromise as it allows habitats to be interpreted over wider strips than a single pass and with the direction of travel in both directions (Mackie, *et al*, 2006). One disadvantage of using towed fish side-scan sonar is that speed over the ground is usually restricted to about 5 knots, though more sophisticated systems using multiple pulses can operate at higher speeds allowing faster coverage of a survey area. A compromise also has to be made on range settings. When surveying a bed in the Irish Sea at 30 m depths, 150 m range settings were found to give the best compromise between detail and coverage per survey line (Lindenbaum *et al*, 2008). A further advantage of using side-scan sonar on *M.modiolus* beds is that marks made by towed fishing gear often show up particularly well, allowing monitoring of this type of impact. Often it is possible to distinguish marks made by scallop dredges, from beam trawls or otter trawls. In the case of scallop dredges used in gangs it is sometimes possible to count the number of dredges on each gang bar. Where beds have been closed to towed fishing gear side-scan surveys can be a useful way of checking for infringements.

(C) Multi-beam Echo Sounder. Reef wave-form features at the scale created by *M.modiolus* can sometimes show up on multi-beam records. Much depends on whether the undulations are sufficient to be detectable and distinguishable from other bed forms. To a lesser extent the *M.modiolus* bed may show as having different back-scatter characteristics on the multi-beam records. At both a North Wales bed and one off the Isle of Man, where the mussels are almost totally embedded in gravel waves, multi-beam showed appropriate bed features.

(D) Boomer. Low frequency sounder systems intended for investigating shallow sub-bottom profiles can be used to show how much biogenic reef may have built up over the basement layer it was founded on.

Most important in any use of sonar equipment in surveying biotopes is that there is adequate ground truthing to confirm that the features observed do correspond to those created by the mussels. Given the rapidity of developments in sonar equipment, data processing software and display methods using GIS and terrain modelling, it is not appropriate to recommend any particular type of equipment or software.

In the context of ecosystem-based management, *M.modiolus* beds can often be mapped in some detail using a suite of acoustic methods, backed up by ground truth observations with cameras or diving, plus limited collecting of samples.

Cameras (video and still)

Where *M.modiolus* forms dense beds they are usually visible on the seabed. The exceptions are where the amount of epifauna growing on them obscures the actual mussels, but even then, differences in the epifauna will often show where the mussels are situated.

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 stll directly downward. The video record will give an overview at relatively low resolution of the presence or continuity of the bed plus an impression of the unevenness of the bed while the still camera will give a series of higher resolution images that allow more of the associated fauna to be identified. Still images will often show the open siphons of the living *M.modiolus*. Using off-the-shelf digital still cameras and flash units in pressure housings and set to fire at intervals (15 sec – 1 min), numerous "quadrat" shots can be obtained from short duration (10 – 20 min) sledge deployments.

Generally the best results are obtained by towing the sledge slowly (0.4 – 0.8 Knots) into the current. With an extra monitor in the wheelhouse, speed over the ground can more easily be seen and adjusted. Towing into the current results in any plume stirred by the sledge being carried away from the field of view and it is easier for the towing vessel to steer. In strong tide locations, camera deployments may have to be limited to periods near slack water. Drop-down video can also be used for ground truthing. Because of vessel motion it is difficult to hover sufficiently close to the bed and impacts of the frame cause plumes that obscure the images so results are generally less easy to interpret than those from towed sledges. An advantage for drop-down, apart from time used in deployment and recovery, is in geo-referencing. With towed gear allowance has to be made for lay-back between the GPS on the ship and the sledge on the seabed. USBL acoustic systems are available to overcome this problem if more precise geo-referencing is needed to closely match particular small features between sonar and the visual images. General operating protocols for video are given by Coggan *et al,* on the MESH web site (www.searchMESH.net).

Visual imaging will often allow enough epifaunal taxa to be recognised for a *M.modiolus* bed to be allocated to a particular EUNIS classification type (subject to those variants not fitting any particular category). Differences in bed types with an abundance of soft epifauna such as *Alcyonium digitatum* from those with more barnacles can be readily seen. 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*.

Diving

Beds in relatively shallow water (<30 m) can be monitored by diving, which allows more detailed examination and sampling to check species identities. Counting the mussels *in situ* by divers is more effective than from remote images; nevertheless it is difficult to standardise counting between observers (Sanderson *et al*, 2008). With multiple layers in the clumps of dense beds, divers considerably underestimate the numbers present, as demonstrated when comparisons have been made with actual samples, sorted in the laboratory (Rees *et al*, 2008). Because of the stony nature of the substrata on which *M.modiolus* beds lie, divers using manual and suction sampling methods can be more efficient than grabs in sampling the associated infauna and crevice fauna.

When detailed monitoring is required, acoustic beacons on fixed benthic frames can be used to allow divers to return to precise locations on a bed and check the continuity of particular reef structures (Sanderson *et al*, 2001; Sanderson *et al*, 2008). This method has been successfully employed for nearly 10 years at a site off North Wales, beacon batteries being changed annually.

Grab and dredge sampling

The crevice and infauna of *M.modiolus* beds are important in the ecosystem functioning of this habitat. Limited physical and hence destructive sampling is thus unavoidable to monitor these components and the size frequency distributions as well as the presence of mussel spat living amongst the clumps. Grabs such as 0.1 m^2 long-arm Van Veen types will work, though the presence of stones and shell limits reliable closure. Owing to patchiness in the mussel beds multiple replicates need to be taken, followed by post-sampling stratification unless video-assisted targeting of mussel clumps is used. In the Bay of Fundy, Wildish and Fader (1998) used a 0.5 m^2 grab with a video camera mounted on it to collect clumps of *M.modiolus*. Where small scattered patches of *M.modiolus* were detected in strongly tide-swept areas using side-scan, the patches were sampled by using a small dredge (Rees, 2005). The deployment method was similar to that for an anchor dredge, that is, dropping it down on the target, and letting the ship drift away until the dredge was felt to catch briefly before recovering it.

Annex 3: Original evaluation against the Texel-Faial criteria for which the habitat was put on the OSPAR List

Nomination by the UK for *M.modiolus* beds to be placed on the OSPAR List cited sensitivity, ecological significance and decline with information also provided on threat. The nomination was for all OSPAR regions.

Decline

Decline in the extent of *M.modiolus* beds has been recorded within the OSPAR Maritime Area, for example in studies along the coast of the UK which have shown a clear decrease of this habitat over the period from the 1950s to the 1990s (Magorrian *et al*, 1995; Hill *et al*, 1999; Jones *et al*, 2000).

Scallop dredging, which is undertaken using heavy metal dredges, usually with large prominent metal teeth along the leading edge, is known to have caused widespread and long-lasting damage to beds in Strangford Lough, Northern Ireland (Magorrian, 1995). Surveys in 2003 reveal the virtual elimination of horse mussel beds within the lough (J. Breen, EHS, pers. comm.). The beds of *M.modiolus* off the Isle of Man are reported to have become progressively much more scattered and less dense over the years (Jones 1951), although not surveyed in detail. The effect on associated communities has also not been studied, although it is known that the very large barnacle *Chirona* (*Balanus) hameri*, which used to be abundant in this particular community, has not been found there recently.

Sensitivity

M.modiolus is a long-lived species and individuals within beds studied around the UK are frequently 25 or more years old. The species is considered to be highly intolerant to substratum loss, abrasion and physical damage. As recruitment is sporadic, varying with season, annually, with location, and hydrographic regime, and is generally low, it may take many years for a population to recover from damage, if at all (Tyler-Walters, 2001).

The fragility of individual *M.modiolus* is not particularly high nor are reefs thought to be particularly fragile; however very physical activities such as impacts by towed fishing gear are known to be damaging, not only by disruption and flattening of clumps and larger aggregations, with reduction in the value of the habitat, but also by damage, and presumably mortality, to individual *M.modiolus.* It should be noted also that the shells of old individuals can be very brittle due to the activities of the boring sponge *Clione celata* (Comely, 1978).

Ecological significance

The species composition of *M.modiolus* beds is variable and is influenced by the depth, degree of water movement, substratum and densities. Three main components are:

- Very dense aggregations of living and dead *Modiolus* shells which form the frame work in a single or multiple layers.
- A rich community of free living and sessile epifauna and predators.

- A very rich and diverse community which seeks shelter in the crevices between the *M.modiolus* shells and byssus threads and flourishes on its rich sediment.

Brown & Seed (1977) recorded 90 invertebrate taxa associated with *Modiolus* clumps in Strangford Lough, with most of the major groups well represented. Holt and Shalla (unpublished) found 270 invertebrate taxa associated with *Modiolus* reef areas to the north-east of the Isle of Man, and suggested that this was likely to be an underestimate, particularly in terms of sponges and infauna. Because of the abundant epifauna and infauna *Modiolus* beds have been considered to support one of the most diverse sublittoral communities in North-west Europe (Holt *et al.,* 1998).

The possible role of *Modiolus* reef communities in providing a nursery refuge for other species is occasionally mentioned in the literature but does not appear to have been investigated. Dense growths of bushy hydroids and bryozoans could conceivably provide an important settling area for spat of bivalves such as the scallops *Pecten maximus* and *Aequipecten opercularis*, adults of which are often abundant in nearby areas.

The byssus threads of *M.modiolus* have an important stabilising effect on the seabed, binding together living animals, dead shells and sediment particles. As *M.modiolus* is a filter feeder the accumulation of faeces and pseudofaeces probably represents an important flux of organic material from the plankton to the benthos.

Relevant additional considerations

Changes in relation to natural variability

Many aspects of the reproduction, development and growth of *M.modiolus* seem to be highly variable. Natural fluctuations in spawning, settlement and recruitment into adult sizes occur in some beds, with predation of young mussels probably being very influential. These must affect the population structure over periods of a few years, but in the long term they seem to be stable features.

Dense reefs and beds are thought in general to be very stable in the long term, despite somewhat intermittent recruitment in some cases. This is based upon observations that reefs are consistently found in the same place over long time periods, but to what degree the *M.modiolus* population structure, physical nature of the reefs, or the associated community structure might vary does not appear to have been studied. The variable nature of recruitment in at least some populations demonstrates that some variation in *M.modiolus* population structure with time must occur, but this has not been described in any detail (Holt *et al.,* 1998).

Predation of young *M.modiolus* by crabs and starfish, in particular, appears to be important. Factors affecting the proportion of young *M.modiolus* surviving through to the size at which predation appears no longer to be a serious threat have not been studied, although in comparison with *Mytilus* reefs, which are composed of much younger animals, the effect of one or two ‘bad years’ of recruitment would be far less serious. It is suspected that juveniles living within the mass of adult byssus threads have greatly enhanced chances of survival, in which case infaunal *M.modiolus* could be at a disadvantage since the byssus may be largely inaccessible.

Expert judgement

More information is needed on the extent and status of this habitat. However, under the concept of precaution, the inclusion of this habitat is considered as sensible, until more research on its status is completed given the observed impacts and decline in well-studied locations, and the demonstrated threat to this habitat from certain fishing methods that are widespread in the OSPAR Maritime Area.

ICES evaluation

OSPAR (2001) considered this habitat to be threatened and/or declining across the whole OSPAR area. Evidence for the decline of and threat to *M.modiolus* beds was then considred to be "strong" across the whole OSPAR area. The view of ICES is that the literature only supports evidence of threat in some parts of the OSPAR Area. They concluded that the need for more information on this habitat is essential and under the concept of precaution, the inclusion of this habitat should be considered as sensible until more research on the status of this habitat is completed (ICES, 2003).

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ISBN 978-1-906840-65-5
Publication Number: 425/2009