Assessment of maerl beds in the OSPAR area and the development of a monitoring program

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Maerl (*Lithophyllum dentatum*) at Kenmare River, south-west Ireland
(Photograph courtesy of Peter Tinsley)

1. Introduction

1.1 Background and purpose of this report

The 1992 Oslo Paris Convention (OSPAR) is the current instrument guiding international cooperation on the protection of the marine environment of the North-East Atlantic and covers an area that extends from mainland Europe to the east coast of Greenland and from the Straits of Gibraltar to the North Pole. The Convention entered into force on 25 March 1998 and 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.

A major element of the current programme of OSPAR work on species and habitat conservation under the Biodiversity Committee has been the development of criteria (known as the Texel-Faial criteria) to identify those species and habitats in need of protection, conservation, and where practical, restoration and/or surveillance or monitoring (OSPAR, 2006). Maerl beds were one of a number of habitats on the OSPAR Initial List in 2004. Under Annex V of OSPAR, free-living red calcareous algae collectively known as maerl are listed as threatened species. The ICES evaluation concluded that maerl beds should be a high priority for the whole OSPAR area.

The assessment of maerl for OSPAR is based on the following questions:

- What is the distribution and extent (habitats) or population of species and how have these changed over time?
- What is the condition of the species or habitat and how has this changed over time?
- What are the threats to the species and habitat, where do they occur and at what level and how are these changing over time?

OSPAR has also agreed that for the first habitat assessment should comprise:

- A collection of information on the distribution, extent and quality of each habitat in the OSPAR region;
- An update of the evaluation of each habitat against the selection criteria (global importance, local importance, rarity, sensitivity, ecological significance and decline);
- A forecast of what is likely to happen to the habitat up to at least 2020 given what is known about human activities considered to be impacting the habitat and measures that have been agreed for its protection;
- An evaluation of any potential threats to the habitat and a recommendation on any further measures, including on currently impacting activities.

This report provides an updated review of these topics, and provides an initial assessment of maerl throughout the OSPAR region. In addition, the report makes recommendations on cost-effective and practical monitoring techniques for this habitat. It has been collated on behalf of the Department of the Environment, Heritage & Local Government (DEHLG) in Ireland and is similar in format to a recent assessment of *Modiolus modiolus* beds produced for OSPAR by the UK Government (MASH 06/6/8-E(L), 2006). This paper is preliminary as surveys of maerl distribution and anthropogenic impacts on maerl are ongoing in several areas within the OSPAR region.

1.2 Working definition of maerl beds

'Maerl' is a Breton word used to describe live and dead accumulations of unattached coralline algae (Lemoine, 1910). The working definition of maerl adopted by OSPAR for habitat mapping is as follows (OSPAR, 2006).

> "Maerl" is a collective term for several species of calcified red seaweed (e.g. *Phymatolithon calcareum*, *Lithothamnion glaciale*, *Lithothamnion corallioides* and *Lithophyllum dentatum* and *L. fasciculatum*) which live unattached on sediments. In favourable conditions, these species can form extensive beds, typically 30% cover or more, mostly in coarse clean sediments of gravels and clean sands or muddy mixed sediments, which occur either on the open coast or in tide-swept channels of marine inlets, where it grows as unattached nodules or 'rhodoliths'. Maerl beds have been recorded from a variety of depths, ranging from the lower shore to 30 m depth. As maerl requires light to photosynthesize, depth is determined by water turbidity. In fully marine conditions the dominant species is typically *P. calcareum*, whilst under variable salinity conditions such as sealochs, beds of *L. glaciale* may develop. Maerl beds have been recorded off the southern and western coasts of Britain and Ireland, north to Shetland, in France and other western European waters.

This definition refers mostly to the UK, but other types of maerl habitat occur within the OSPAR area. Typically maerl is found on sediments, but it can accumulate on areas of bedrock. Maerl beds characterised by *Lithophyllum dentatum* occur in Ireland (De Grave et al., 2000), and *Lithothamnion tophiforme* is thought to be the main maerl-forming species in colder parts of the OSPAR area (Kjellmann, 1883; Adey & Adey, 1974), such as the east coast of Greenland, around Spitsbergen and on the northern coasts of Norway. The taxonomy of the species that make up maerl beds in the Azores is still poorly known. This being the case, we suggest modifying the definition of maerl used by OSPAR as follows:

> 'Maerl' is a collective term for various species of non-jointed coralline red algae (Corallinaceae) that live unattached. These species can form extensive beds, mostly in coarse clean sediments of gravels and clean sands or muddy mixed sediments, which occur either on the open coast, in tide-swept channels or in sheltered areas of marine inlets with weak current. As maerl requires light to photosynthesize, the depth of live beds is determined by water turbidity, being found from the lower shore to 40 m or more. Maerl beds may be composed of living maerl, dead maerl or varying proportions of both.

1.3 Correlation with habitat classification schemes

In the European EUNIS habitat classification (2004 version; http://eunis.eea.eu.int/eunis/habitats.jsp) maerl beds are subdivided into two habitat types, depending on whether *Phymatolithon calcareum* (A5.511) or *Lithothamnion glaciale* (A5.512) is the dominant maerl-forming species present. In the National Marine Habitat Classification for Britain and Ireland (Connor *et al.*, 2004) maerl habitat has been subdivided into six types depending on the characteristic species present (**Table 1**).

Table 1. Types of maerl habitat recognised by the EUNIS and National Marine Habitat Classification for Britain and Ireland classification schemes.

Habitat type	European EUNIS classification	Britain & Ireland classification
Beds of maerl in coarse clean sediments of gravels and clean sands, which occur either on the open coast or in tide-swept channels of marine inlets (the latter often stony).	A5.51	SS.SMp.Mrl
Maerl beds characterised by *Phymatolithon calcareum* in gravels and sands.	A5.511	SS.SMp.Mrl.Pcal
Upper infralittoral maerl beds characterised by *Phymatolithon calcareum* in gravels and sand with a wide variety of associated red seaweeds.	A5.511	SS.SMp.Mrl.Pcal.R
Lower infralittoral maerl beds characterised by *Phymatolithon calcareum* in gravels and sand with a variety of associated echinoderms.	A5.511	SS.SMp.Mrl.Pcal.Nmix
Live maerl beds in sheltered, silty conditions which are dominated by *Lithothamnion corallioides* with a variety of foliose and filamentous seaweeds.	A5.51	SS.SMp.Mrl.Lcor
Shallow, sheltered infralittoral muddy plains with *Lithophyllum fasciculatum* maerl.	A5.51	SS.SMp.Mrl.Lfas
Upper infralittoral tide-swept channels of coarse sediment in full or variable salinity conditions with *Lithothamnion glaciale* maerl 'rhodoliths'.	A5.512	SS.SMp.Mrl.Lgla

1.4 Common characteristics of maerl beds

Maerl habitats comprise loose-lying non-jointed coralline red algae (Corallinales, Rhodophyta) that can build up over millennia to create carbonate-rich gravel deposits that form isolated habitats of high benthic biodiversity (Hall-Spencer, 1998; Grall & Hall-Spencer, 2003, Grall *et al.*, 2006). Maerl growth requires light for photosynthesis and usually occurs in areas with clear water and current; it can live close to estuaries in varying salinity, with episodes of rather high turbidity. Laboratory experiments show that smothering by fine sediment, lowered oxygen concentrations and the presence of hydrogen sulphide are particularly damaging to maerl-forming algae (Wilson *et al.*, 2004). Maerl beds exhibit high productivity, especially of microphytobenthos (Martin *et al.*, 2006), which fuels the trophic web and supports high abundances of charactistic invertebrates (Grall *et al.*, 2006).

The conservation importance of maerl beds is increasingly recognised, not only because of their longevity and high biodiversity, but also due to potential benefits for commercial fisheries. Maerl beds can harbour high densities of broodstock bivalves and act as nursery areas for the juvenile stages of commercial species such as cod (*Gadus morhua* L.), edible crabs (*Cancer pagurus* L.) and scallops (*Aequipecten opercularis* (L.)), which are attracted to the complex 3-dimensional unconsolidated structure (Kamenos *et al.*, 2004).

2 Distribution, extent and quality of the habitat in the OSPAR region

2.1. Distribution

2.1.1 Overall distribution in OSPAR region

The distribution of maerl in the OSPAR region, based on a range of data sources, is shown in **Fig. 1**. Maerl is recorded in 96 fifty-km squares. The database compiled for this report will be made available to OSPAR and comes with references to site records where possible.

Maerl is absent from large areas of Europe, such as most of the North Sea, the Baltic Sea, the Irish Sea and eastern English Channel. There is scant information for the northern OSPAR area although there are unpublished reports of maerl having been found by divers at fjordic locations off Greenland and Spitzbergen. Most records are from Atlantic coasts off Norway (Kjellmann, 1883; Adey & Adey, 1973; Freiwald & Henrich, 1994; Husa et al., 2004) and Denmark (King & Schramm, 1982) in the north, to mainland Portugal and the Azores in the south. In Ireland, maerl is widely distributed in the south and south-west, and in the UK it occurs off the south and west coasts and north to Shetland (Birkett *et al.,*

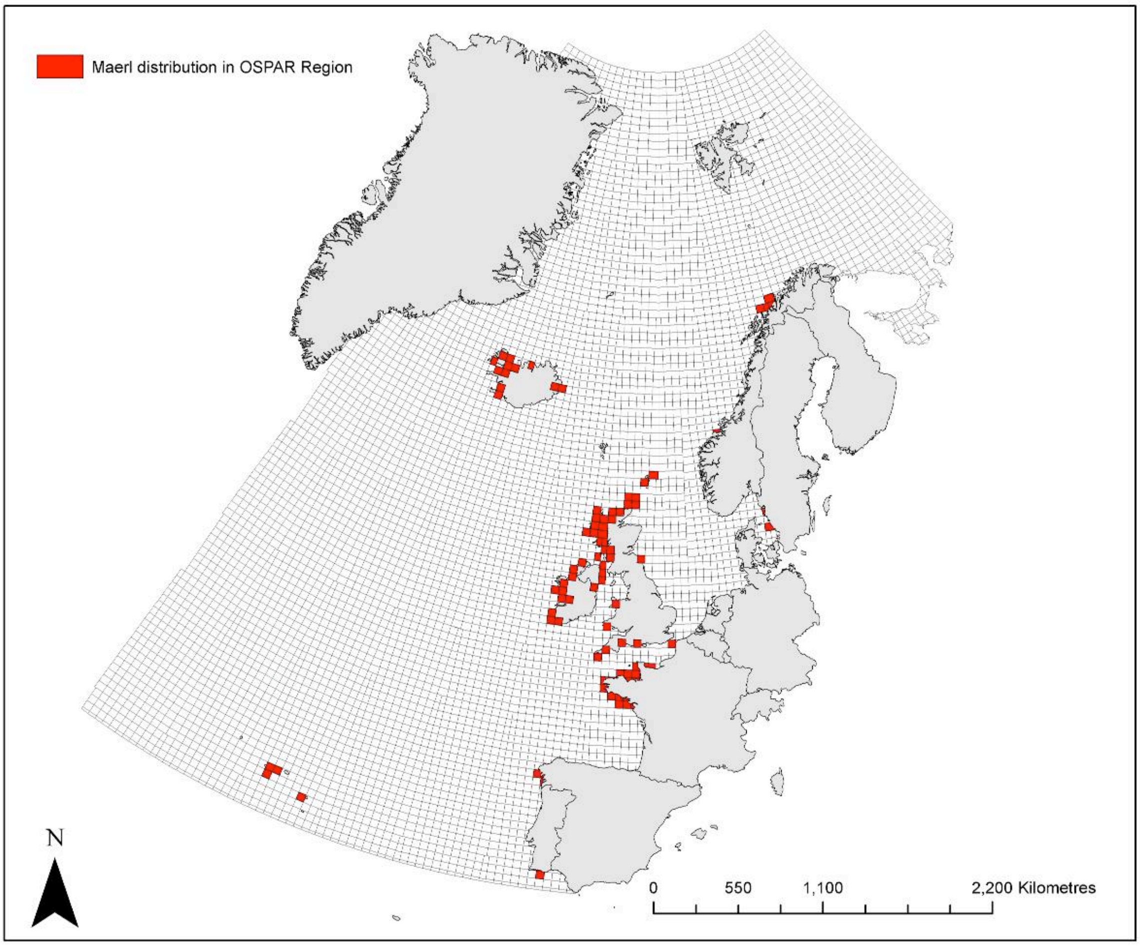

Fig. 1: Distribution of 50 km squares containing maerl beds in in the OSPAR maritime area (based on data for Galicia supplied by Viviana Peña Freire and Ignacio Bárbara, for Brittany by Jacques Grall, the UK National Biodiversity Network for the UK, NPW and EHS for Ireland, Estibaliz Berecibar and Rui Santos for Portugal, and Karl Gunnarson for Iceland; other records collated by Emma Jackson and Jason Hall-Spencer at the University of Plymouth). Note that maerl may occupy only a small area within a grid square.

1998; Hall-Spencer *et al*., 2006). It is particularly abundant in Brittany (Cabioch 1970; Grall & Hall-Spencer, 2003) and in the rias of Galicia in Spain (Adey & McKibbin, 1970; Peña & Bárbara, 2006, 2007a, b).

Along the coastline of mainland Europe beds of live maerl typically occur in depths of less than 40 m and can extend onto the lower shore. In Galicia**,** live maerl is known to 40 m depth, and is found to greater depths in the Azores. Data are lacking at present, but the deepest maerl beds in the OSPAR region are likely to occur around the offshore oceanic islands of the Canary Islands (E. Soler-Onis, personal communication) and Madeira. Maerl beds have been recorded at only one site in the Azores (http://marinera.net/about/partners/documents/MarinERA_Portugal_Rev1.pdf) Likewise, in the Mediterranean, maerl beds are known to occur at depths up to 100 m in the clear waters off Corsica and Malta.

The distribution of maerl within particular regions of the OSPAR area is covered in detail in the following sections.

2.1.2 Distribution on the Atlantic coast of France

French maerl deposits have a long history of research (Paturel, 1898; Lemoine, 1910; Hamel & Lemoine, 1953, Cabioch 1968, 1969, 1970). Biotope mapping in the 1960s and 1970s provided detailed descriptions of Breton maerl bed communities and distinguished

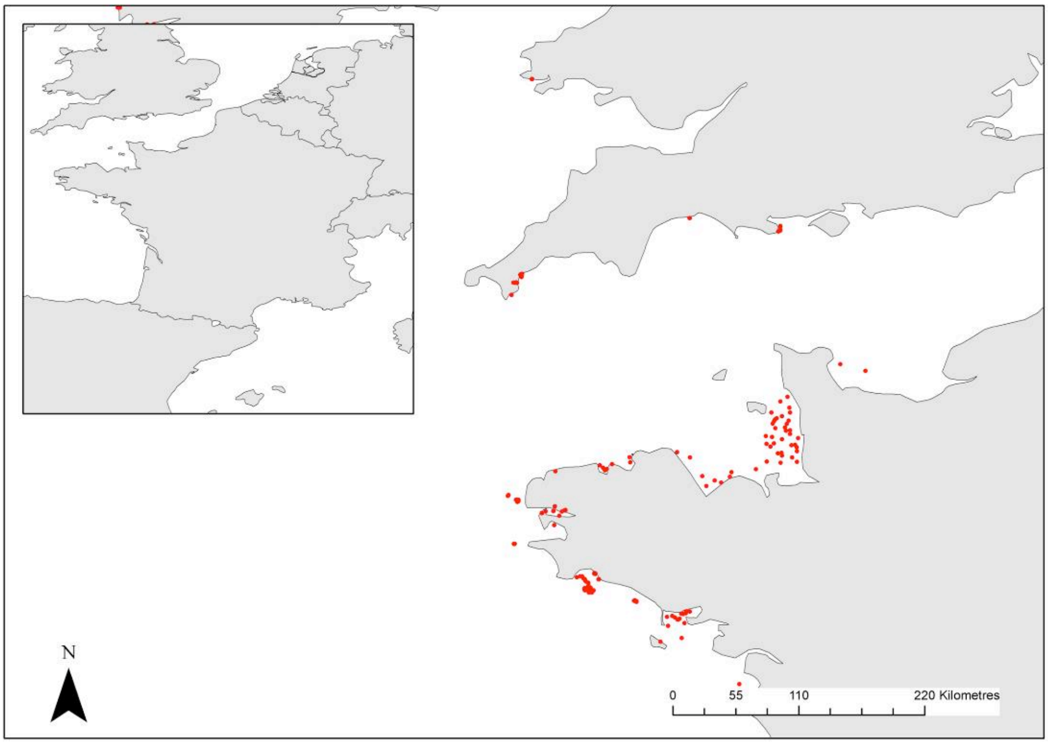

Fig. 2. Map showing the location of maerl beds in Brittany, England and Wales. Data for Brittany supplied by Jacques Grall.

them from other types of gravel shown on sedimentary maps of the area. The total number of Breton maerl beds (**Fig. 3**) is currently undergoing assessment, although they can be small (10–100 m^2) and are therefore difficult to map. However, Gautier (1971) recorded at least 70 maerl beds >1 km^2 from around 17 bays and islands in the region.

On the Atlantic coast of France, maerl is distributed mainly around the coasts of Brittany. A few maerl beds have been recorded in the eastern part of the Channel, but reports need to be confirmed. Maerl is absent from the southern Bay of Biscay from the Loire estuary to the basque country. The largest concentration of maerl in the western Channel occurs around the Chausey archipelago, with numerous extensive beds distributed in the shallow western and southern part of these islands. Other extensive beds are those of Belle-Ile, Bay of Concarneau, Glenan, the Bay of Brest and the Bay of Morlaix. Numerous smaller maerl beds occur within the complex coastline off Brittany, some of them having been discovered recently.

The species composition of the bank varies according to the biotope (see section 1.2). Of the two dominant species, *Phymatholithon calcareum* occurs in 'open' areas, and *Lithothamnion corallioides* is found in more semi-enclosed bays and inlets, but in general both species are grow together. There is a *Lithophyllum dentatum* bed in the eastern part of the Bay of Brest.

2.1.3. Distribution in Iceland

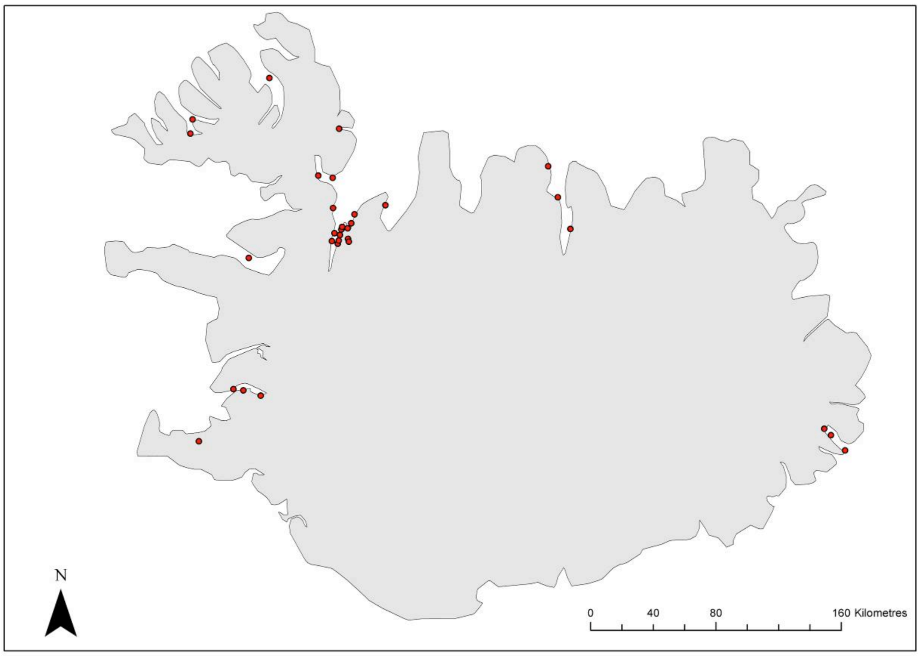

Fig. 3. Known distribution of maerl habitats in Iceland (from various datasets including personal communications from Karl Gunnarson, Reykjavik and Ken Collins, Southampton).

Aðalsteinsdóttir and Garðarsson (1980) sampled a grid of stations in central Hvalfjord, showing coralline algae to be present close to the northern shore from Grunartangi to Katanes. Karl Gunnarsson (personal communication) reports that maerl is widely distributed in northern Icelandic fjords, deep within the fjords but probably exposed to some wave action. His study at Langanes, Arnafjörður (Gunnarsson, 1977) shows the maerl to be situated on an exposed headland within the fjord. This is similar to its distribution at Hvammur, Hvalfjörđur (K. Collins & J. Mallinson, unpublished observations).

2.1.4. Distribution in Ireland

In Ireland, maerl is widely distributed in the mid-west and the southwest (**Fig. 1**). The minimum number of maerl beds in Irish waters is estimated to be 35-40, with the majority (c. 65-70%) in Galway Bay and along the Connemara coastline (**Fig. 10**; De Grave & Whitaker, 1999), ranging from 0.5 to 15 m below chart datum (De Grave, 1999). The majority of the maerl beds in Ireland are located between 0 to 20 m with the exception of one off Inishman found in depths of 20 to 30 m (M. Guiry, pers. comm.). More detailed distribution is provided in section 2.2.3.

De Grave (1999, table 3) gives the area of the bed at Inishmaan as 4 km^2**,** Mannin as 2 km^2**,** and Eastern Galway Bay as 20 km^2; the paper acknowledges that Kilkieran Bay, Co. Galway, which was not mapped as it is in an SAC, has some of the largest deposits.

2.1.5. Distribution on Atlantic coasts of Spain

Former studies on Galician maërl beds by Hamel (1928), Miranda (1934), Donze (1968), Koldijk (1968), Cadée (1968), Seoane-Camba and Campo-Sancho (1968), Mora (1980), Otero-Schmitt and Pérez-Cirera (2002) and Bárbara et al. (2004) were carried out only in the southern rías. Information on the flora is scarce as these studies were of short duration and, restricted to isolated locations. Recently, Bárbara et al. (2006) and Peña & Bárbara (2006, 2007a,b) have reported work in progress on the distribution and ecology of maerl beds off the Atlantic coast of Spain and show that maerl habitat is mainly distributed in the rias. It is most widespread in the Ria de Arousa where maerl occurs on parts of the lower shore down to depths of 40 m. The main species are *Phymatolithon calcareum* and *Lithothamnion corallioides* (Adey & McKibbin, 1970; Peña & Bárbara, 2004) although recent studies confirm the occurrence of *Mesophyllum* sp. as a maerl-forming species in one shallow maerl bed in the Ría de Arousa (V. Peña, personal communication).

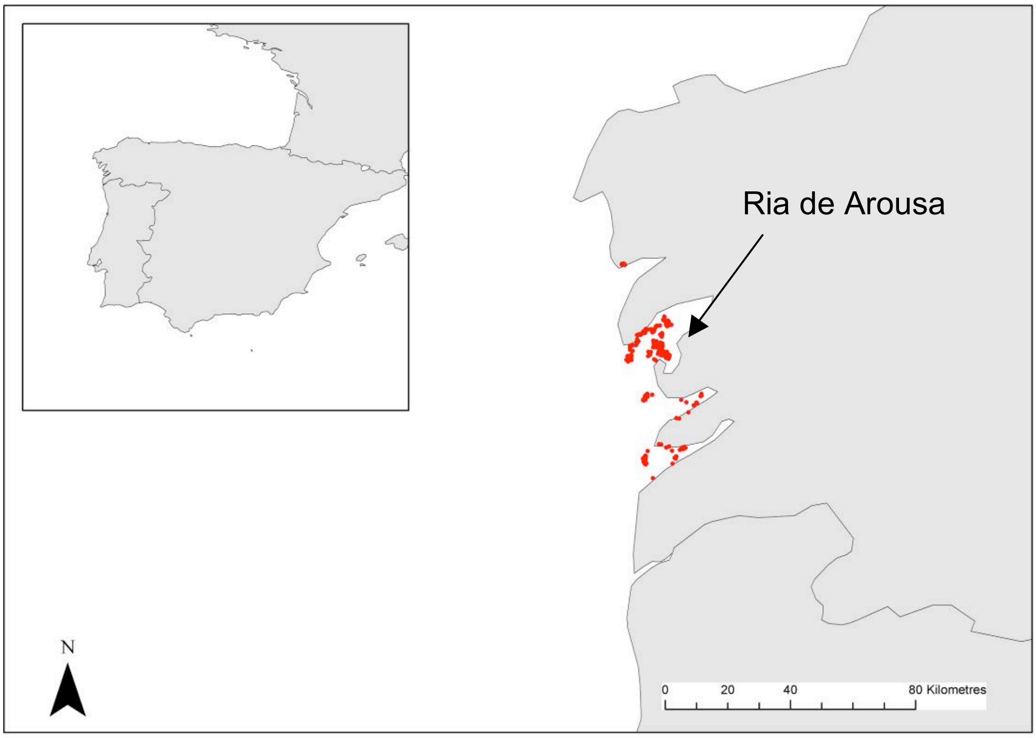

Fig. 4. Distribution of maerl habitats in Galicia, NW Spain (inset, map of the Iberian Peninsula). It is most common in the Ria de Arousa (data from Peña & Bárbara, 2007a).

2.1.6 Distribution on Atlantic coasts of Portugal

Information is sparse but maerl beds are known only from the Algarve (Fig. 5).

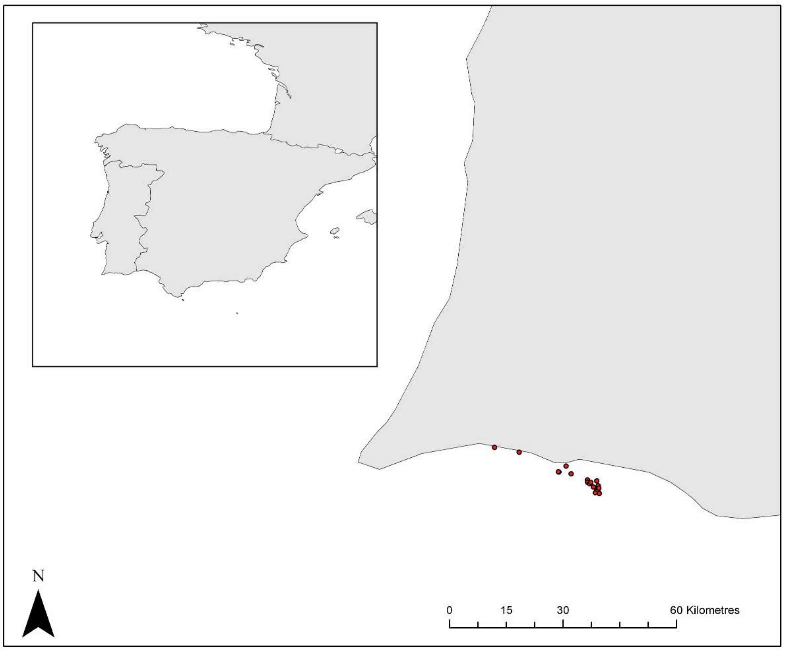

Fig. 5. Distribution of maerl habitats on southern (Algarve) coast of Portugal from data supplied by Estibaliz Berecibar and Rui Santos (inset, map of the Iberian Peninsula).

2.1.7. Distribution in the UK

The distribution of maerl around the coasts of the UK is patchy, with the majority of maerl beds located on the west coasts of Britain. The vast majority of UK maerl records are from the fjordic coastline of western Scotland (**Fig. 6).** Maerl beds are relatively abundant off Orkney, Shetland and throughout Scotland's west coast with over 100 sites reported (Scott & Moore, 1996), more than in any other European country. Maerl is absent from the east coast of mainland Scotland.

In England, maerl beds are rare (**Fig. 2**). In Cornwall there is an extensive bed of live maerl growing on the St. Mawes Bank in the Fal estuary (Farnham & Bishop, 1985). Maerl also occurs off the Isle of Man (Veale *et al*., 1999) and the mouth of the Helford River and small amounts are known to occur in the Isles of Scilly and near Lundy (Birkett *et al*., 1998). The maerl beds off the Dorset coast have been mapped (**Fig. 8;** Mitchell & Collins, 2004).

In Wales, limited and patchy maerl beds have been recorded around the Pembrokeshire Islands and the Lleyn peninsula and a more extensive bed (subfossil and live) in Milford Haven (Birkett *et al*., 1998) (**Fig. 3**).

Relatively small maerl beds occur off the open coast of Northern Ireland in Antrim (**Fig. 10**) and in the sealoughs, particularly Strangford Lough.

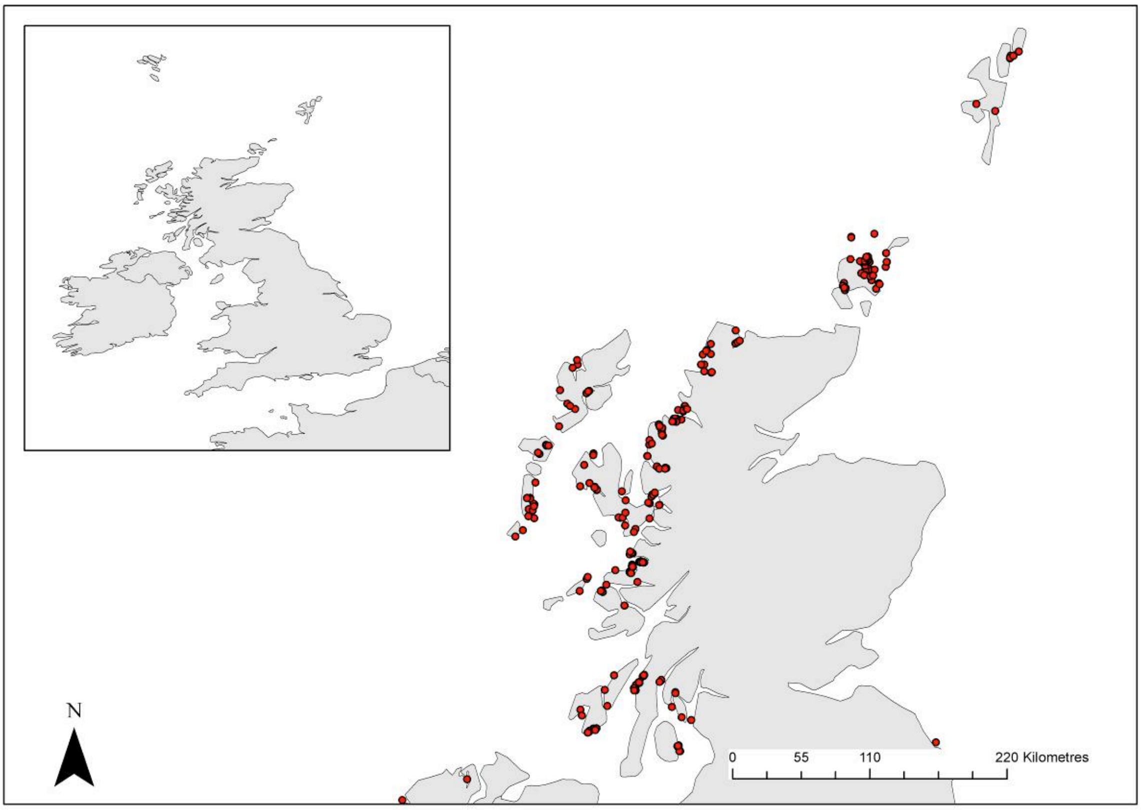

Fig. 6: Map showing the locations of recorded maerl beds in Scotland (and extreme north of Ireland; data provided by NBN). Note that symbols represent the approximate locations of maerl beds and not their extent. Inset, coastline of Britain and Ireland.

The species composing the beds vary geographically, as noted above (section 1.2). Irvine & Chamberlain (1994) report that *Phymatolithon calcareum* forms maerl at sites from

Dorset to Shetland along the western coasts of the UK whereas maerl-forming *Lithothamnion glaciale* has a northern distribution in the UK and *Lithothamnion corallioides* is restricted to the southwest.

2.2 Extent

2.2.1 Extent within the OSPAR area

Maerl is recorded in 96 fifty-km squares within the OSPAR area. At present the total area of maerl habitat occupied cannot be estimated. In many cases only point records are available, from which it is not possible to extrapolate to extent. However, more maerl beds are currently being mapped. In the following sections we present examples where detailed maps are available, and in some cases total area occupied has been calculated. For one maerl bed off England, the density of live maerl has been determined.

2.2.2. Extent within Brittany, France

In the 1960s Breton maerl beds covered several square kilometres, the largest being the Glenan bed. Dredging has seriously impacted the extent of this maerl bed however (see section **3.7**). Some maerl beds that 30 years ago would have appeared in **Table 2** are not mentioned since they have been entirely destroyed.

Only a few beds (e.g. Glenan, Trevignon) have recently been mapped in France with accurate acoustic methods. However, despite considerable heterogeneity in the mapping methods, **Table 2** provides data for live maerl/dead maerl surface area of the most important French beds. It should be noted that some large beds need to be re-assessed in terms of their composition.

There are long-term data sets (over 50 or 100 years) for some beds that show the change of maerl extent over time. Thus, it is possible to show how live maerl was totally removed from the northern Glenan bed within a 50-year period (1910-1960) and later how the thickness of the deposits decreased during industrial exploitation (1970-1990); finally, when industrial exploitation was restricted to particular areas (1995-2005), the removal of maerl left deep trenches. On the other hand, repeated surveys in the northern basin of the Bay of Brest shows that management of urban effluents has allowed an increase of live maerl cover over a 15-year period.

Table 2. Surface area (ha) of live, dead, unknown (to be reassessed) of the main French maerl beds

Sites	Live maerl	Dead Maerl	Unknown maerl	Heterogeneous sediments (including maerl)	Total
Rade de Brest	4657	0	0	0	4657
Belle-Ile	1215	10	3	306	1534
Chausey	1000	6252	9552	0	16803
Douarnenez	895	0	0	0	895
Mousterlin/les Moutons	666	0	1386	0	2052
Trévignon	615	65	0	1	681

Baie de Morlaix	522	0	25	0	547
Lannion	359	0	0	0	359
Camaret	106	81	0	0	187
Les Pourceaux	89	600	0	0	689
Côte de Granit Rose	67	0	0	185	251
Les Glénan	56	649	0	310	1015
Golfe du Morbihan	17	0	1	2823	2841
Ile de Groix	10	0	0	2169	2179
Ile de Sein	10	0	0	0	10
Golfe Normandy-Breton	0	0	9416	0	9416
Baie de Saint-Brieuc	0	0	5441	0	5441
Houat et Hoedic	0	0	2276	0	2276
Lorient	0	0	1058	0	1058
Saint Nazaire	0	0	489	0	489
Cap Fréhel–Saint-Malo	0	0	218	192	410
Quiberon	0	0	355 (?)	0	355
Entrance of Golfe du Morbihan	0	0	318	0	318
Plouguerneau	0	0	5	0	5
Granville	0	0	0	39855	39855
Bricquebec	0	0	0	20505	20505
St-Vaast-la-Hougue	0	0	0	10894	10894

2.2.3 Extent within Iceland

No data are available for the extent of any beds in Iceland.

2.2.4 Extent within Ireland

In Ireland, De Grave (1999) mapped eight areas and indicated that 60 km^2 of seabed was occupied by maerl (De Grave *et al.,* 2000). Since then, DEHLG have to date mapped an additional four (Kingstown Bay, Clew Bay, Kilkieran Bay/Greatmans Bay, Valentia Harbour) in detail as part of an ongoing maerl mapping programme. They also mapped Kenmare Bay using broadscale mapping c. 5 years ago. Remote sensing surveys in Counties Clare (I bed), Cork (8 beds), Co. Galway (11 beds) and Kerry (2 beds) indicated that 37.46 km^2 of seabed was occupied by maerl (De Grave *et al.,* 2000) and it was considered that another 20 km^2 occurred in areas not mapped, most notably in Kilkieran Bay. To date beds, on the west coast, in Kilkieran Bay and Mannin Bay have been mapped An example of the map data for Co. Galway and Co. Clare is shown (**Fig. 7**). in detail.

Fig. 7. Distribution of some mapped beds of live and dead maerl) on mid west coast of Ireland, with inset showing position of coastline. Distribution mapped by DEHLG (Ireland).

2.2.5. Extent within Algarve, Spain

No data are available.

2.2.6. Extent within Galicia, Spain

Maerl is estimated to cover 13.94 km^2 in the Ria de Arousa (**Table 3**) where several beds have >90% live maerl cover; the total estimate for all the rias is 23.45 km^2 (**Table 3**).

Table 3. Extent of maerl beds in Galicia, Spain (from Peña & Bárbera, 2007b)

Maerl bed regions	Number of beds previously known in region	Present known number of beds	Estimated surface area occupied (km^2)
Ría de Ferrol	0	3	0.17
Ría de Muros-Noia	7	8	1.97
Ría de Arousa	46	47	13.94
Ría de Pontevedra	6	29	3
Ría de Aldán	0	3	0.06
Ría de Vigo	8	18	4.31

Total	**67**	**108**	**23.45**

2.2.7. Extent within the UK

A few maerl beds in the UK have been mapped with some precision, although the total area of maerl occupied is rarely reported. In England the first studies of maerl beds took place in the Fal Estuary investigating the geology and infauna of the deposits (Hardiman et al., 1976; Bosence & Wilson, 2003). Recently Mitchell & Collins (2004; **Fig. 7**) made detailed maerl surveys off Swanage in Dorset using pipe dredge and diver surveys, involving collecting all the live maerl from 0.5 m^2 quadrats placed on the seabed, weighing it, and analysing the data with GIS. The maerl density data were presented so that they spanned the entire maerl bed area. Physical parameters were correlated with the maerl distribution. Maerl distribution occured only within a certain depth range, 11.3 m (below chart datum) to 22.6 m. Comparison of near-bed current velocities plotted against maerl densities for each transect showed maerl to be absent at velocities lower than 37 cm/s and above 80 cm/s.

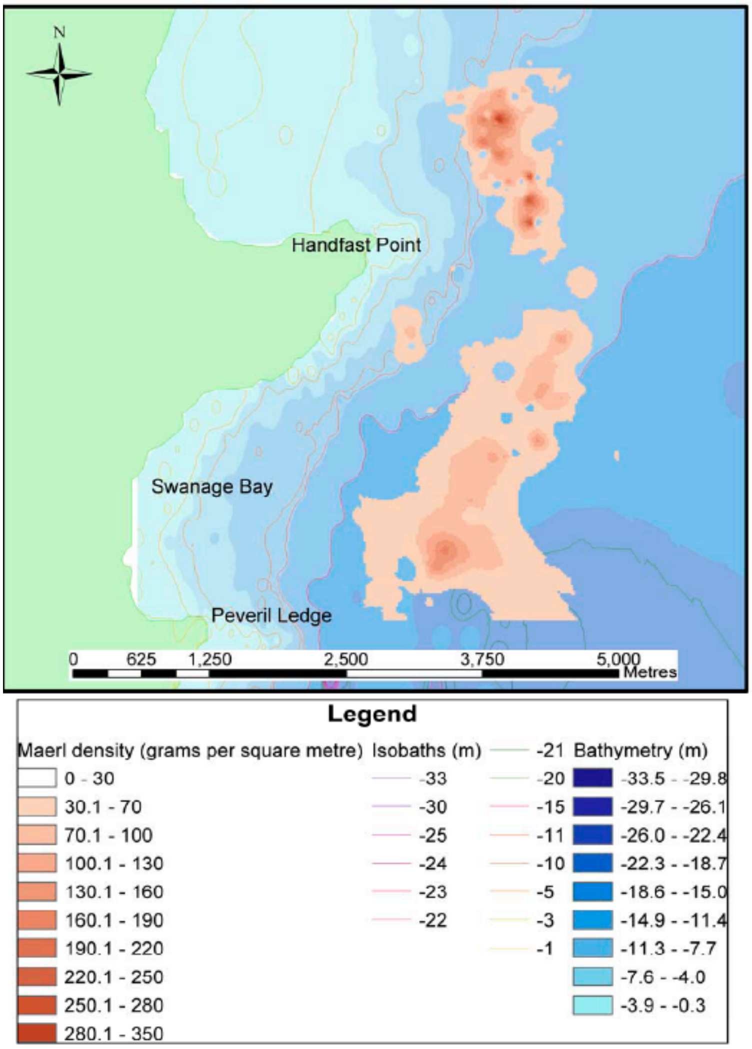

Fig. 8. Maerl bed off Swanage, Dorset (reproduced from Mitchell & Collins, 2004).

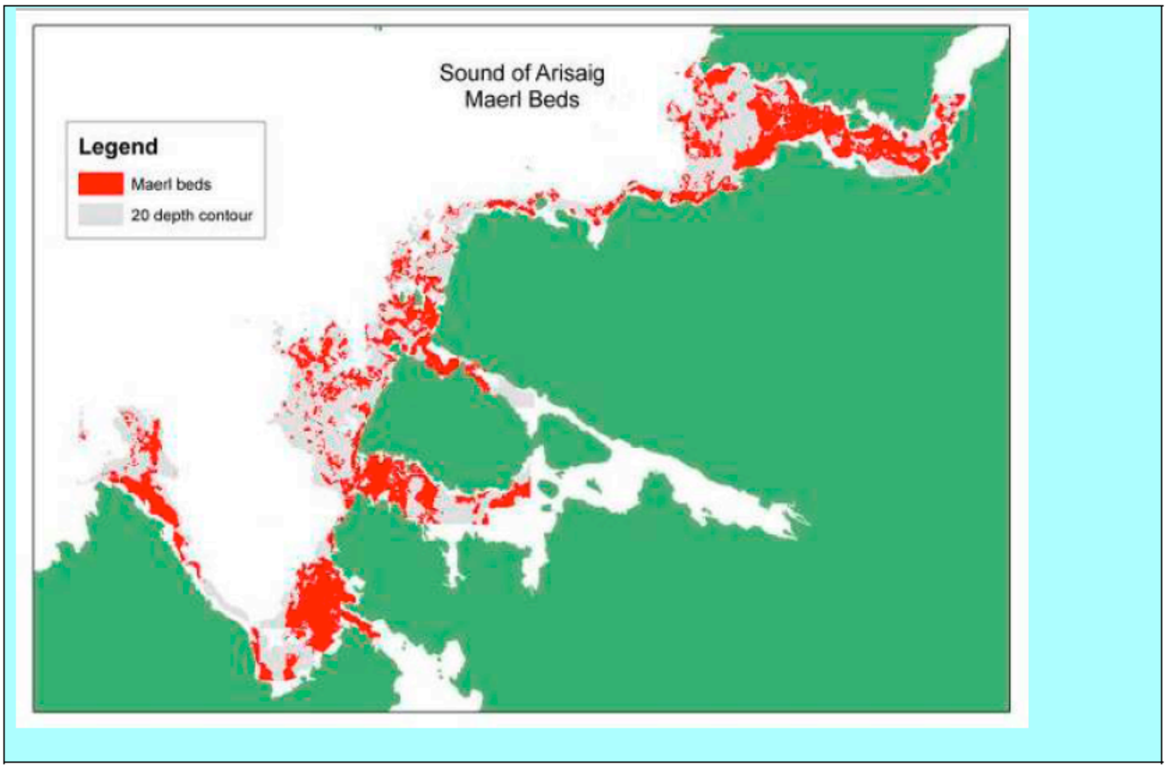

Figure 1. Distribution of maerl beds and sand banks in the Sound of Arisaig cSAC. From Marine SACs LIFE project SNH/HRC

Fig. 9. Distribution of maerl in Sound of Arisaig marine SAC, from Gubbay *et al*. (2006).

In Scotland, a study of sea lochs between 1988-92 for the Marine Nature Conservation Review reported the presence of extensive, rich and diverse beds of maerl in Loch Ailort, Loch Moidart and Loch Ceann Traigh in the Sound of Arisaig. This information resulted in the area becoming a cSAC for its maerl beds as a type of sandbank habitat. A more detailed survey was carried out in 1995 to determine the extent of the habitats and marine communities within in the cSAC to suggest possible boundaries (Fig. 8). Data were collected using acoustic survey techniques backed up with biological sampling (Gubbay *et al*., 2006).

Beds off the coast of Antrim, Northern Ireland, UK, occupy a total area of approximately 7 km^2 (Wilson et al., 2007).

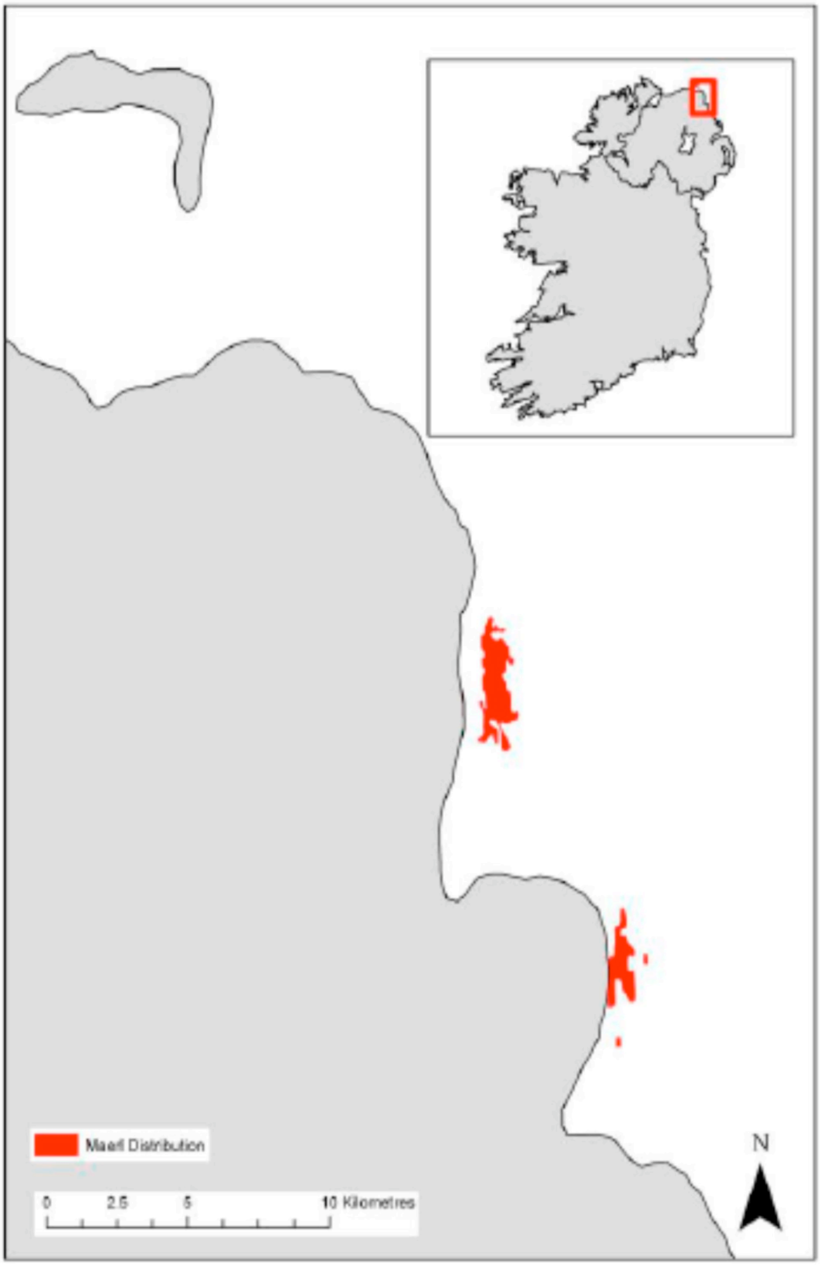

Fig. 10. Beds off the coast of Antrim, Northern Ireland, UK

2.3 Quality

2.3.1 Quality within the OSPAR region

Within the OSPAR region it is believed that the quality of maerl habitats varies greatly, by comparison with a reference quality for each region. In some parts the of OSPAR area, such as Iceland, there are very few impacts on maerl. In other areas there is very good evidence of a decline in quality due to a range of impacts.

2.3.2 Quality within Brittany, France

Throughout the study of Breton maerl grounds, researchers have emphasized the high biodiversity of maerl compared with other sublittoral sediments. More recently this has led to calls for their conservation (Grall & Hall-Spencer, 2003). However, maerl beds in Brittany have been severely impacted by a range of anthropogenic factors (Grall & Hall-Spencer, 2003). In particular, commercial dredging of c. 500,000 tonnes per annum from large beds such as the Glenan bed have irreversibly damaged this and other Breton maerl beds (see Section 2.2). Further problems are associated with eutrophication, which has resulted in an increase in algal biomass at impacted sites (Grall & Glémarec, 1997), and the presence of alien species such as *Crepidula fornicata*. Long term surveys of four maerl beds by the coastal observatory of IUEM show that in the Bay of Brest, management of agricultural and urban/industrial effluent has decreased benthic eutrophication, and permitted an improvement in the quality of beds in the northern bay.

2.3.3 Quality within Iceland

Generally considered to be good though limited commercial extraction is being carried out at one location on the north coast.

2.3.4 Quality within Ireland

In some areas quality is considered to be good whereas in others quality is likely to be reduced due to fishing activities and aquaculture. One area in Co. Cork (Lonehorn Pt., Bantry Bay) is licensed to extract 10,000 t of maërl (M. Guiry, personal communication).

2.3.5 Quality within Portugal

No data are available.

2.3.6 Quality within Galicia, Spain

A serious reduction in maerl cover and the extent of the beds has been detected by a project designed to detect long-term changes in the Galician maerl beds (Peña & Bárbara, 2007). Most of the degraded beds are located within or in the vicinity of the mussel farms that are abundant in the Galician rias. Mussel aquaculture started there in the 1940s, reaching approximately 3400 mussel rafts today (Sánchez-Mata & Mora, 2000). These contribute large amounts of fine sediment and detritus to the bottom (Vilas *et al*., 2005), causing the burial and death of the maerl thalli by reduction of gas exchange around them (Wilson *et al.,* 2004). Other effects are the reduction of structural heterogeneity and complexity of the maerl, reduction in the abundance and diversity of associated flora and the occurrence of non-native species (Peña & Bárbara, 2007a; Peña *et al.,* 2006).

2.3.7 Quality within the UK

Significant declines in quality have been recorded due to maerl extraction in the Fal Estuary, England, which is particularly destructive since this removes the productive surface layer and dumps sediment on any plants which escape dredging, inhibiting habitat recovery (Hall-Spencer, 2005). Although commercial extraction has now been discontinued (Hall-Spencer, 2006), any possible recovery has not yet been investigated. Permanent moorings for pleasure boats could have similar, more localized, effects due to the effects of mooring chains being dragged in circles on the maerl, particular at low tide, although in Northern Ireland damage seems to be largely confined to degrading the size structure of the maerl (Vize, 2005).

In Scotland, scallop dredging in the Firth of Clyde has resulted in the removal of the living maerl thalli from the biotope surface, the loss of the stabilising algae and the disruption of the structure of the maerl bed, and has potentially changed the trophic structure of maerl communities (Hall-Spencer & Moore, 2000a, b). There are around 20 salmon farms presently known to be situated on maerl habitats in Scotland, three of which (in Shetland, Orkney and South Uist) have been surveyed in detail. Each of the fish farms studied has been shown to reduce the quality and extent of maerl habitats (Hall-Spencer *et al*., 2006; Hall-Spencer & Bamber, in press).

In Wales, impacts on the benthic infauna, epifauna and algae have been observed in association with a major industrial construction project in Milford Haven (Camplin, 2007).

3 Evaluation against the Texel-Faial selection criteria

3.1. Introduction

Maerl beds were nominated for inclusion on the OSPAR List in 2006 on the basis of an evaluation of their status according to the Criteria for the Identification of Species and Habitats in need of Protection and their Method of Application (the Texel-Faial Criteria) (OSPAR, 2006). The nomination for inclusion on the list cited the criteria of decline, sensitivity and ecological significance, with information also supplied on threat. The following sections provide an update on this evaluation.

3.2 Global importance

Maerl beds vary in area from tens to thousands of square metres in extent and occur from the tropics to polar waters forming gravels composed of high numbers of usually monospecific thalli (Woelkerling, 1988). Deposits of maerl and rhodoliths are found in many locations and environments around the world, from the Arctic to the tropics (Adey & Adey, 1973; Adey & Macintyre, 1973; Bosence, 1983b). Foster (2001) provided an overview of their worldwide distribution and ecological importance. Maerl beds are particularly abundant in the Mediterranean and Gulf of California, as well as in various other areas of the Pacific and Atlantic Oceans. The largest known beds are off Brazil.

In the nearshore coastal environments of the Gulf of California, Mexico, rhodoliths of *Lithophyllum margaritae* and *Neogoniolithon* sp. form extensive beds of a living coralline matrix overlying soft sandy substrata that cover up to 100% of the sea floor (Hinojosa-Arango & Riosmena-Rodriguez, 2004).

Maerl beds are productive communities in temperate coastal ecosystems (Martin *et al.,* 2005, 2007a). Both dead and living maerl deposits are considered to be an important source of subtidal and beach-forming calcareous sediments (Farrow *et al.,* 1978). They are regarded as the carbonate factories of European coasts (Bosence & Wilson, 2003; Martin *et al.,* 2007b) and contribute to the pH balance of seawater (Canals & Ballesteros, 1997).

For the three main maerl-forming species that occur within the OSPAR region (see **Table 4**), the OSPAR distribution is of high global importance. Both *Lithothamnion corallioides* and *Phymatolithon calcareum* are restricted to Europe and the Canary Islands; outside the OSPAR region they are found only in the Mediterranean. *Lithothamnion glaciale* has a wider northern and western Atlantic distribution but the majority of beds globally are probably within the OSPAR region.

3.3 Regional importance

Three main species of maerl are reported to occur in the OSPAR region, with at least a further six species known to contribute to deposits in certain areas (**Table 4**). For the three main maerl-forming species, the OSPAR distribution is of high regional importance, constituting the majority of their areal extent and biomass. The minor maerl-forming species often occupy only small areas and are endemic to the OSPAR region, particularly Ireland.

Table 4. Maerl-forming species in European waters (modified from Birkett *et al*., 1998)

Species	Geographical range
Major maerl-forming species	
Lithothamnion corallioides (P. & H. Crouan) P. & H. Crouan	Forms maerl from Ireland and the southern British Isles to the Mediterranean; Canary Is.
Lithothamnion glaciale Kjellman	Forms maerl from Arctic Russia, N. Norway and W. Baltic to northern British Isles; Arctic Canada to USA, Greenland
Phymatolithon calcareum (Pallas) W. Adey & McKibbin	Forms maerl from S. Norway and W. Baltic to the Mediterranean
Minor maerl-forming species	
Lithophyllum dentatum (Kützing) Foslie	Species status and limits uncertain; records from Ireland and Britanny
Lithophyllum racemus (Lamarck) Foslie (including British records of *L. duckeri* Woelkerling)	Limits uncertain; now thought to be a Mediterranean endemic with erroneous records from S. England and Ireland
Lithophyllum fasciculatum (Lamarck) Foslie	Ireland, UK and Brittany
Lithophyllum hibernicum Foslie	Species status uncertain; Ireland
Lithothamnion lemoineae Adey	Distribution unclear; encrusting plants reported from Northumberland but known as maerl only from Orkney
Lithothamnion sonderi Hauck	Encrusting thalli from Mediterranean to W. Baltic and Norway (Nordland) but reported as maerl only in Scotland

The conservation importance of maerl is increasingly recognised in the NE Atlantic (Donnan & Moore, 2003) and led to the inclusion of maerl on the OSPAR list of threatened and/or declining habitats (OSPAR, 2006). The European Union's Council Directive 92/43/EEC on the conservation of natural habitats and of wild fauna and flora (the Habitats Directive) gives legislative protection to maerl with *Phymatolithon calcareum* and *Lithothamnion corallioides* included in Annex V of the Directive. This requires Member States to take appropriate management measures to ensure that any exploitation is compatible with the species being maintained at a favourable conservation status. Maerl is included as a key habitat for Ireland and the UK within the Annex I habitats 'large shallow inlet and bay' and 'sand banks which are slightly covered by seawater at all times' such that a number of Special Areas of Conservation (SACs) designated under the Directive contain maerl beds. Apart from harbouring high biodiversity, it has been shown that the protection of maerl beds can benefit commercial fisheries. This is because maerl grounds can harbour high densities of broodstock bivalves (Hauton et al., 2003; Hall-Spencer et al., 2003) and act as nursery areas for the juvenile stages of commercial species such as cod (*Gadus morhua*), crabs (*Cancer pagurus*) and scallops (*Aequipecten opercularis*), which are attracted to the complex three-dimensional structure (Kamenos *et al*., 2003, 2004).

3.4. Rarity

Within the OSPAR area, maerl is thought to be absent from the coastlines of Belgium, the Netherlands, Germany and Sweden; it is known from very few locations off England and Denmark. In contrast, maerl is widespread along the westernmost coasts of Norway, Scotland and Ireland and is also recorded at numerous locations around Brittany in France and Galicia in Spain. There is insufficient information at present on the distribution of maerl to determine its rarity around the Azores, Greenland and Iceland. The distribution of particular species is shown in **Table 4**.

3.5 Sensitivity

Maerl is very sensitive to substratum loss, smothering, increase in suspended sediment, abrasion and physical disturbance which can prevent light reaching the living maerl and therefore halt photosynthesis (Jones *et al.,* 2000). The presence of dead maerl beds in areas where sediment dredging has previously been carried out suggests that dredging may have caused the extinction of some maerl beds in Ireland and Wales. The impacts of any damage to maerl beds are long lasting because the key habitat structuring species has a very poor regenerative ability (Hall-Spencer & Moore, 2003). Extremely slow growth rates have been recorded for maerl in Ireland, England, France, Norway, Scotland and Spain. These are of the order of tenths of millimetres to one millimetre per year (Adey & McKibbin, 1970; Potin et al., 1990; Bosence & Wilson, 2003; Blake & Maggs, 2003). The "recovery potential" of maerl beds in relation to a single event causing mortality has previously been categorized by OSPAR (IMPACT, 1998) as 'poor', meaning that partial recovery is likely within 10 years and full recovery may take up to 25 years. We would caution that maerl recovery may never occur, if for example a bed is removed by dredging or completely smothered by sediment. Little is known about the reproductive mechanisms of this species. Spores can potentially disperse long distances although if dispersal is dependent on vegetative propagation, then distances will be extremely limited.

3.6 Ecological significance

Maerl-forming algae produce a heterogeneous hard substratum in various depositional environments including muddy, sandy and gravel substrata, or mixtures of these. Faunal studies show that maerl beds form isolated habitats of high benthic biodiversity and biomass (Cabioch, 1968; Keegan, 1974; Hardiman *et al.,* 1976; Bosence, 1979; Mora Bermúdez, 1980; Grall & Glémarec, 1997a,b; Hall-Spencer, 1998; BIOMAERL, 1999; Hall-Spencer *et al.,* 2003; Hauton et al., 2003; Steller *et al*., 2003) and that some support rare, unusual or endemic species of macroalgae, polychaetes and amphipods (Southward, 1957; Cabioch, 1969; Blunden *et al.,* 1977, 1981; Myers & McGrath, 1980, 1983; Maggs & Guiry, 1982, 1987, 1989; Maggs, 1983; O'Connor & Shin, 1983; De Grave & Whitaker, 1999; Clark, 2000; Bárbara *et al.,* 2004; Peña & Bárbara, 2007).

Maerl beds are an important habitat for a wide variety of marine animals and plants which live amongst or are attached to the nodules, or burrow in the coarse gravel or fossil maerl beneath the top living layer (Grall & Glémarec, 1997). The beds studied to date have been found to harbour a disproportionately high diversity and abundance of associated species in comparison with surrounding habitats, and some of these species are confined to the maerl habitat or rarely found elsewhere. Dead maerl also has an ecological importance, supporting diverse communities, although these have been reported to be less rich than those which in live maerl beds (Keegan, 1974).

Maerl beds may also be important nursery areas for commercially valuable molluscs and crustaceans. This aspect has not been well studied but there is good evidence that they are nurseries for at least a few species e.g. the black sea urchin *Paracentrotus lividus* in maerl deposits in Ireland and scallops on maerl beds in France and the west of Scotland (Thouzeau, 1991; Keegan, 1974; Birkett *et al*., 1998). They also provide structurally complex feeding areas for juvenile fish such as Atlantic cod, and reserves of commercial brood stock for species such as *Pecten maximus, Venus verrucosa* and *Ensis* spp. (Hall-Spencer *et al*., 2003).

3.7 Decline

A number of studies indicate that maerl beds have declined in both extent and quality in the OSPAR Area. Most Breton maerl beds are affected by human activities and the only pristine grounds remaining are small compared to the extensive maerl beds that covered several square kilometres in the 1960s (Grall & Hall-Spencer, 2003). For example, one of the largest maerl beds in Brittany (Glenan) was covered in living maerl until maerl extraction began in the beginning of the 20th century, and it seems that by 1960-70 all live maerl had been removed, but also that industrial extraction has considerably lowered the maerl layer – see above). When surveyed in 1999 live maerl was very rare over most the bank and no macrofauna were observed in grab and core samples in the extraction zone (Grall & Hall-Spencer, 2003). Some of Britttany's extensive maerl beds have been severely impacted by sewage discharge (Grall & Glémarec, 1997) whilst the ecology of others has been altered by the invasive species *Crepidula fornicata* (Grall & Hall-Spencer, 2003). Extraction of both living and fossil deposits have depleted beds in the Fal estuary in England, although maerl extraction was banned there in 2005 (Hall-Spencer, 2005). Extraction of maerl from a single bed in Iceland has taken place for the last two years, at a rate of approx. 10,000 m^3 p.a (K. Gunnarson, personal communication).

Hall-Spencer & Moore (2000) recorded declines in maerl habitat off the west coast of Scotland due to scallop dredging with extensive declines over the past 100 years. A living maerl bed with abundant large thalli and nests of the gaping file shell *Limaria hians* has become a bed of predominantly dead maerl with few, small, live thalli and no *L. hians* (Hall-Spencer & Moore, 2003). Mariculture has also led to the decline of maerl habitat due to smothering by fine particulates. Mussel farms in the rias of Galicia (Biomaerl, 1999; Peña *et al.,* 2006, Peña & Bárbara, 2007a) and Bantry Bay, Ireland (Hall-Spencer, personal observations) salmon farms in Scotland and Ireland (Hall-Spencer et al., 2006) have caused damage. In Galicia, Peña & Bárbara (2006, 2007a) found that most of the well-preserved maerl beds are located in protected areas such as the Islas Atlanticas National Park, or restricted to shallow areas less than 9 m depth where mussel rafts cannot be stationed.

3.8 Threat

In Europe, maerl has been dredged from both living beds and fossilised deposits for use as an agricultural soil conditioner as well as use in animal food additives and water filtration systems. Although quantities were initially small, by the 1970s a peak of around 600,000 tonnes were extracted per year in France (Briand, 1991). Due to the very slow rate of growth, maerl is considered to be a non-renewable resource and, even if the proportion of living maerl in commercially collected material is low, extraction has major effects on the wide range of species present in both live and dead maerl deposits (Hall-Spencer, 1998; Barbera *et al.,* 2003)

As well as the direct effect of the physical removal of the maerl during extraction, there are other direct and indirect impacts from muddy plumes and excessive sediment load, caused by the dredging activity, which later settle out and smother associated and surrounding communities.

Damage to the surface of beds is also caused by heavy demersal fishing gear, from pollution by finfish and shellfish aquaculture operations in inshore waters, and suction dredging for bivalves. Coastal construction and increases in agricultural and sewage discharges may also have some impact if they increase sediment loads or result in the excessive growth of ephemeral species of macroalgae around maerl beds (Birkett *et al.,* 1998; De Grave *et al.*, 2000).

Impacts have also been reported on benthic communities at and around extraction sites. In Brittany large scale maerl extraction over the last 30 years has removed and degraded the habitat. Other major impacts include the spread of the invasive gastropod *Crepidula fornicata*, industrial waste, sewage pollution, aquaculture and demersal fishing, all of which have increased sharply since the 1970s and are causing widespread damage to Breton beds (Grall & Hall-Spencer, 2003, BIOMAERL team, 2003). For example at Glenan in France there was a clear change from 1969 (before suction dredging started) to 1999 (Grall & Hall-Spencer 2003). Before intense dredging the community was diverse and typical of Breton maerl beds but it has since become an impoverished muddy sand community. In 1969 the habitat was described as a clean maerl gravel with low silt content supporting abundant suspension feeding bivalves. Now the habitat is of muddy sand dominated by deposit feeders and omnivores. Similar changes have also been recorded in Ireland (De Grave & Whittaker, 1999). Habitat complexity is also much reduced by bivalve dredging (Hall-Spencer *et al.,* 2003).

Several workers (Mora, 1980; BIOMAERL team, 1999; Barberá *et al*., 2003; Peña *et al*., 2006) have highlighted the negative impacts of aquaculture on maërl communities, due to the increased deposition of detritus and fine sediment derived from mussel cultures. It settles out on the substratum, resulting in the burial of maerl and decline in its abundance. Adey & McKibbin (1970), BIOMAERL team (1999), De Grave & Whitaker (1999), Grall and Hall-Spencer (2003) and Wilson *et al*. (2004) have all linked the deposition of these fine sediments with a reduction in water movement and restriction of gaseous exchange around the maërl. The changes in the Galician maërl beds (a reduction in cover, degradation and disappearance of some maerl beds especially those within or in the vicinity of mussel aquaculture areas) have important implications for their conservation.

4. A forecast for the habitat up to 2020

4.1 Human activities considered to be impacting maerl beds

Relevant human activity: Extraction of sand, stone and gravel, constructions, landbased activities, aquaculture/mariculture, traffic infrastructure (dredging), placement and operation of cables and pipelines, fishing, hunting, harvesting, tourism and recreational activities.

Category of effect of human activity: Physical – Substratum removal, substratum change, increased siltation, turbidity changes, water flow rate changes; Biological – physical damage to species, displacement of species, removal of non-target species, introduction of alien species, changes in population or community structure or dynamics.

There is no doubt that many human activities can and do damage maerl beds. Commercial dredging of maerl deposits is particularly destructive since this removes the productive surface layer and dumps sediment on any plants which escape dredging, inhibiting habitat recovery (Hall-Spencer, 1994). Fishing activities can also cause damage with scallop dredging on French and UK maerl beds having significantly reduced the complexity, biodiversity and long-term viability of these habitats (Hall-Spencer *et al*., 2003; Hily *et al.,* 1993; MacDonald *et al.,* 1996). Video and direct observation of the effects of scallop dredging in the Upper Firth of Clyde (UK) have revealed dredge teeth penetrating 10 cm into the maerl, crushing maerl fragments and killing them by burial. Four months later there were less than half as many live maerl thalli as in control undredged areas (Hall-Spencer, 1995, 1998). Scallop dredging activity has also been reported to result in severe disruption to the maerl bed and associated flora and fauna in France, although where there are restrictions certain types of damage may be reduced. Some areas have therefore remained productive for commercial bivalves, and deep-burrowing organisms can survive in large numbers (Hily & Le Fol, 1990; Hall-Spencer *et al.,* 2003).

Sewage pollution has also been directly linked to the loss of maerl beds. In the Bay of Brest, for example, two maerl beds studied 50 years ago have changed from dense deposits of living maerl on sandy mud mixed with dead maerl to heterogeneous mud with maerl fragments buried under several centimetres of fine sediment with species-poor communities dominated by opportunists (Grall & Glémarec, 1997; Grall & Hall-Spencer, 2003).

Although some damaging activities have been curtailed, it can safely be predicted that many of the impacts on maerl beds will continue to increase in their effects until 2020. The removal of extraction licences in Cornwall, England (Hall-Spencer, 2005) is an important step as the level of damage that can result from extraction is clearly seen in Brittany. Increased pressure on sealochs for aquaculture will make it more difficult to prevent impacts of aquaculture on maerl. Three factors may mitigate some of these problems: (1) increased regulation of various marine activities, broadly under the umbrella of Marine Spatial Planning; (2) the possibility that more marine reserves, preferably no-take zones, may be designated; and (3) the likely impacts of the Water Framework Directive in improving coastal water quality and thereby decreasing eutrophication.

4.2 Management measures

The main management measure which would assist the conservation of this habitat is protection from physical damage. This would require halting direct extraction from maerl beds and stopping fishing in maerl beds using gears that damage the structure of the beds and the associated species. A four-year EU project on maerl in Europe (BIOMAERL) recommended a presumption of protection of all maerl beds as they are effectively non-renewable resources. Other proposals from this work include the prohibition on the use of towed gear on maerl grounds, moratoria on the issue of further permits for the siting of aquaculture units above maerl grounds and measures to limit the impacts that might affect water quality above maerl beds (Bárbera *et al.,* 2003).

The main requirement is for accurate mapping so that Marine Spatial Planning can be used to protect maerl beds. In Scotland, for example, SNH will be providing information on maerl bed locations in relation to proposed new sewage outfalls (D. Donnan, personal communication).

Closed areas for particular types of fishing are used to protect certain habitats and species in the NE Atlantic and could also be applied to protect this habitat. Management plans for fisheries can take maerl into account (D. Donnan, personal communication). This is a matter that falls within the remit of fisheries organisations rather than OSPAR, although OSPAR can communicate an opinion on its concern about this habitat to the relevant bodies and introduce any relevant supporting measures that fall within its own remit (such as Marine Protected Areas).

Two of the more common maerl-forming species, *L. corallioides* and *P.calcareum,* are listed in Annex V of the EC Habitats Directive. In some locations maerl is also a key habitat within some of the Annex I habitats of the Directive and therefore given protection through the designation of Special Areas of Conservation. In the UK maerl is the subject of a habitat action plan under the UK Biodiversity Action Plan.

5 Evaluation of potential threats and measures

5.1 Potential threats

The majority of threats for the future are already being experienced and have been discussed in the previous section. Additional potential threats from future climate change, resulting in ocean acidification and range shifts due to temperature changes, are evaluated here.

One-third of the carbon dioxide (CO_2) released in the atmosphere via fossil fuel burning is taken up by the ocean (Sabine *et al.,* 2004). As a result, increasing CO_2 partial pressure (pCO_2) in surface water lowers the pH and decreases the carbonate (CO_3^{2-}) ion concentration and the subsequent calcium carbonate ($CaCO_3$) saturation state (Ω). Global ocean models forced with atmospheric CO_2 projections predict surface pH reductions of 0.3-0.5 units by the year 2100 (Caldeira & Wickett, 2005). This is likely to have strong impacts on calcifying organisms such as coralline algae (see review in Kleypas *et al.*, 2006). Previous studies have shown that high pCO_2 (low pH) can negatively coralline algal settlement (Agegian, 1985) and metabolism (e.g. photosynthesis and calcification rates) (Smith & Roth, 1979; Gao *et al.,* 1993). We strongly recommend that studies be carried out on the effects of ocean acidification on maerl beds in the OSPAR region.

Ocean warming could have particularly severe effects on some maerl species due to their fragmented ranges and poor dispersal. Whereas the ranges of widely distributed species can alter in response to climatic change, species with fragmented distributions such as some of the maerl species may be ‘trapped’ within areas that are no longer suitable for them. Only limited knowledge of temperature tolerances and optima are available for some species of maerl (Blake & Maggs, 2004).

5.2 Recommendations on possible measures
5.2.1 Legislation, licensing and management

As noted above, in Galicia well-preserved maerl beds in deeper water are mostly confined to protected areas such as the Islas Atlanticas National Park (Peña & Bárbara (2006, 2007a). Where appropriate, further protection of maerl beds within national, European (Habitats Directive) or OSPAR marine protected area mechanisms should be considered. Where maerl beds already occur within designated sites, management systems may need improvement to ensure adequate protection of the habitat.

5.2.2 Enhancing recruitment

This has never been attempted. The feasibility of possibility of temporarily re-locating maerl in Milford Haven during construction of jetties associated with construction of the Liquified Natural Gas terminal (Camplin, 2007) was considered by CCW but it was thought impractical.

6. Development of a Monitoring Program

6.1. Existing monitoring programs

There is no evidence in the literature of maerl beds having been repeatedly surveyed except in relation to impact studies (Perrins *et al.*, 1995; Hall-Spencer, 2000; Hall-Spencer & Moore, 2000a, b). No time-series studies on maerl beds were identified in the UK by Hiscock & Kimmance (2003). In Britanny, twice-annual (spring and autumn) monitoring is carried out at the following sites: Paimpol (Côtes d'Armor), Banc de Guerheon (Baie de Morlaix, Finistère), Banc des Pourceaux (Molène, Finistère), Camaret (Finistère), Rozegat (Rade de Brest, Finistère), Glénan (Finistère), Trévignon (Finistère), Belle-île sud (île de Belle-île), Chenal du Crouesty (Morbihan) (Hily *et al.*, 2003; http://www.rebent.org/**)**. After an initial phase in 2001-2, since 2003 their strategy has been to inventory the local habitats, with maps, and follow the spatial dynamics of these habitats and their biota over time. Sampling is carried out with Smith-McIntyre grabs at sites with GIS referencing and the surveillance is accessible via interactive maps on the website. The IUEM (European Institute for Marine Studies) station carries out more comprehensive surveys (more frequently, with more parameters such as macroflora and stable isotopes) for the Bays of Brest, Camaret, Iroise and Glenan.

6.2. Development of new monitoring programs

In order to better understand the state of maerl beds across OSPAR and to follow any changes over time it is important to establish suitable long-term monitoring of the distribution, extent and quality of the maerl beds, their key threats, and the effectiveness of any conservation measures put in place. The approach to monitoring of each maerl bed management unit will need to be designed specifically to take into account the threats that may have effects on that bed. In other words, the monitoring program should be targetted at the threat, and its potential impact so that impacts will be detected if they occur.

Under OSPAR, any maerl beds in MPAs and SACs should be monitored to assess condition, and a report be compiled, at intervals of six years. This is the recommended minimum frequency of monitoring for all monitored maerl beds. The features that need to be monitored are

- extent of bed
- percentage of live maerl
- a measure of biodiversity (possible measures are discussed below in section 6.4)
- physical data (e.g. water temperature, turbidity)
- chemical data (e.g. N, P values to determine possible eutrophication)

6.3. Mapping of maerl beds and determination of live/dead maerl

Where resources permit, the initial extent of the bed should be determined by mapping on a grid located using a GIS. The size of the grid squares could vary depending on the size of the maerl bed – very large beds require only relatively coarse grids (km scale) whereas small beds may need fine grids of 100-200 m. The map can be used as a baseline to interpret future changes. Maerl beds are dynamic and minor boundary changes are likely to occur continuously. Rapid remote sensing methods such as side-scan sonar can be valuable for determining overall distribution of maerl beds where beds are thick and extensive, providing they are used with adequate ground-truthing. However, often maerl forms a thin layer over other substrata, or depths are too shallow and channels too narrow to permit remote sensing from survey vessels. Furthermore, little information will be obtained on whether maerl is live or dead. Given that many living maerl beds are found in association with subfossil beds that died 1000-8000 years ago, determining the amount of live maerl is important.

A combination of drop-down digital video and high-resolution still photography, with limited SCUBA diving or grab sampling is ideal as it provides data on the relative abundance of live and dead maerl, and infaunal samples can be obtained by coring or grab sampling. Clearly it is important that the monitoring operations should cause only the minimum possible damage to the bed, particularly where beds are small or particularly rich in biodiversity.

Previous and ongoing mapping programmes adopt a range of methods (or combination thereof depending on environmental conditions and/or available resources) including drop-down digital video and high-resolution still photography, SCUBA diving, and grab sampling which usefully provide data on the relative abundance of live and dead maerl, and infaunal samples can be obtained by coring or grab sampling. For example, a combination of drop-down video and SCUBA ground-truthing was used in Northern Ireland (**Fig. 11**) while SCUBA divers with direct propulsion vehicles are employed in the Republic of Ireland. Clearly it is important that the monitoring operations should cause only the minimum possible damage to the bed, particularly where beds are small or particularly rich in biodiversity.

There seems to be very good potential to use the ratio of live to dead maerl, or the abundance of live maerl, as a proxy for the biota of maerl beds. M. Camplin (2007 and personal communication) has found that in Milford Haven there is a very good correlation between recorded impacts of construction work on the amount of live maerl with the effects on the biota (various measures of invertebrate and algae diversity and abundance). In addition to this, the three-dimensional structure of maerl beds (i.e. depth of live and dead maerl deposits) has potential as an indication of the condition of the bed. In Brittany, reduction in the depth of maerl deposits has had obvious impacts on the biodiversity of maerl beds.

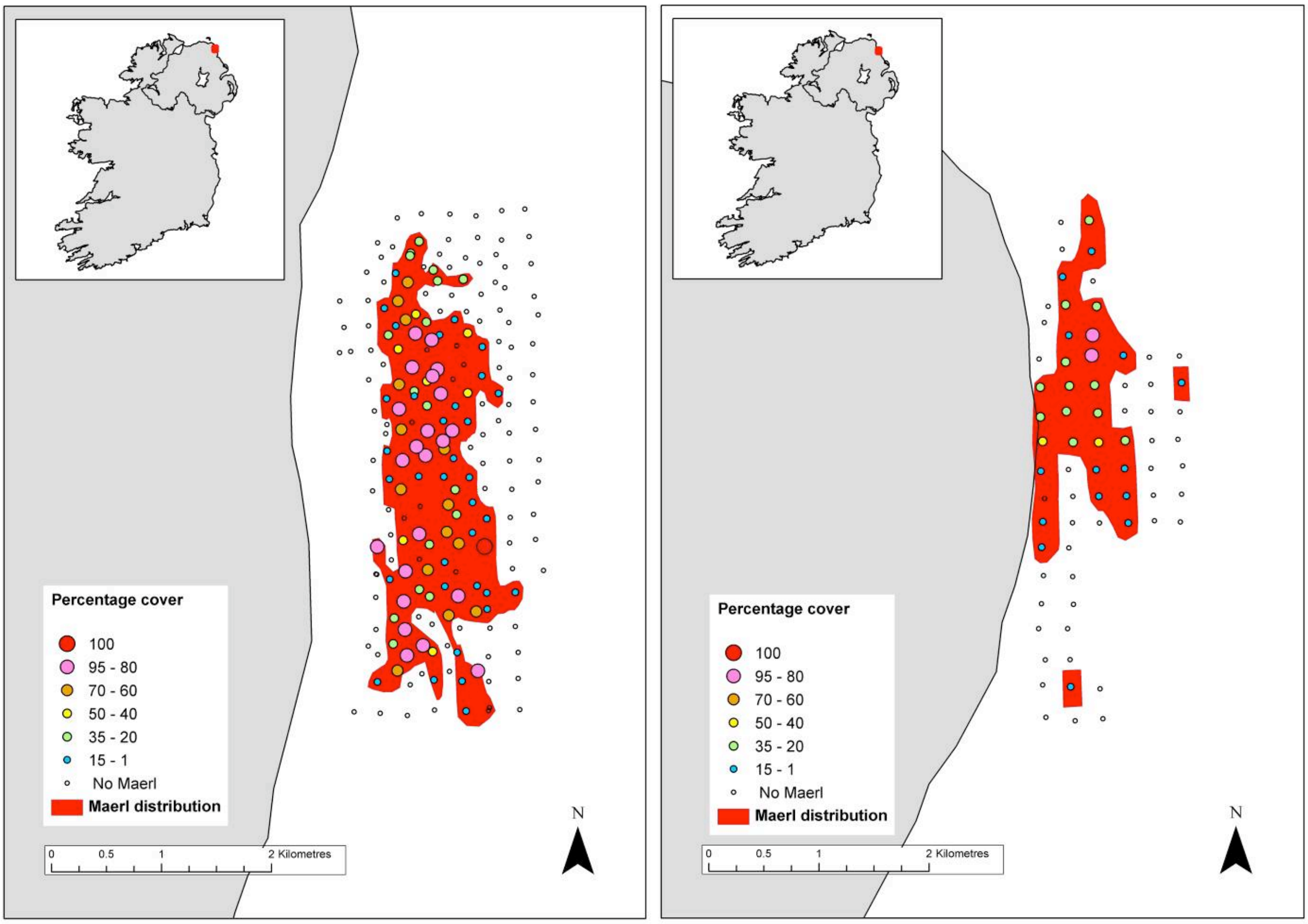

Fig. 11. Distribution and percentage cover of maerl within two maerl beds off the Antrim coast, Northern Ireland (from Wilson *et al.*, 2007).

6.4. Measures of biodiversity for monitoring maerl beds

As maerl beds vary greatly over the OSPAR area, and threats vary between regions, it is not likely that the same measure of biodiversity is appropriate for all of them. Monitoring should be planned to identify changes taking place within particular maerl beds or geographical areas. An example of a group of species that could be monitored semi-quantitatively, and which appear to be sensitive to disturbance of maerl beds, is a suite of small red algae that are more or less confined to maerl. *Cruoria cruoriaeformis, Halymenia latifolia* and *Gelidiella calcicola* are found on maerl beds in Britain, Ireland, Britanny and Galicia, and were listed as nationally scarce species that are potentially threatened, in a review carried out in 2006 by MarLIN for Natural England. Both *C. cruoriaeformis* and *G. calcicola* are recognised by Nationally Important Marine Feature/Biodiversity Action Plan (NIMF/BAP) as priority species. Monitoring the presence of these species at regular intervals would be valuable, and is realistic as they can be identified underwater by divers after training. The time of year of monitoring would ideally be late summer, but other times could be used as long as the seasonality of the maerl biota is taken into account in analysing the results. During monitoring of the impact of nearby civil engineering work on maerl beds in Milford Haven (Camplin, 2007), it was found that both *C. cruoriaeformis* and *G. calcicola* were detrimentally affected by comparison with more generalist macroalgae (M. Camplin, personal communication).

Infaunal species vary greatly in abundance seasonally and a possible ‘sentinel species’ indicating disturbance was identified by BIOMAERL (P.G. Moore, pers. comm.). The diversity of the polychaete *Hesione pantherina* was much reduced at eutrophicated sites in Brittany compared to non-impacted sites; this species may be especially sensitive to eutrophication. Until sentinel species are identified and their population dynamics better characterized, all species and their abundances should be monitored regularly, as far as possible, using appropriate methodology for each life-form. Monitoring of the effect of civil engineering on maerl beds in Milford Haven using various techniques demonstrated that quantitative analyses of infaunal cores clearly revealed impacts on both biodiversity and abundance of the invertebrate fauna (Camplin, 2007). Coring is relatively expensive, however, and where resources are restricted, epifauna might provide a reasonably robust measure of biodiversity.

Regular checks for the appearance of newly established aliens is likely to be a cost-effective approach as the Water Framework Directive will also require monitoring of alien species. Maerl beds can support a wide range of invasive species including *Heterosiphonia japonica, Dasya sessilis, Neosiphonia harveyi, Sargassum muticum, Undaria pinnatifida, Colpomenia peregrina* and *Codium fragile* subsp. *fragile*.

The baseline data collected in relation to the biodiversity associated with each maerl bed in initial surveys should be used as a starting point and similar methodologies should be used during monitoring to make the data comparable. The addition of further baseline data to existing datasets for the site is important in the context of future monitoring of the conservation status of the site.

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