



## Background Document for Maërl beds



## 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.

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## Background Document for Maërl beds



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

## Executive Summary

This Background Document on maërl 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 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 maërl beds in the OSPAR List is followed by an assessment of the most recent information on its status (distribution, extent, condition) and key threats prepared during 2009-2010. Chapter 7 provides recommendations for the actions and measures that could be taken to improve the conservation status of the habitat. In agreeing to the publication of this document, Contracting Parties have indicated the need to further review these proposals. Publication of this background document does not, therefore, imply any formal endorsement of these proposals by the OSPAR Commission. On the basis of the further review of these proposals, OSPAR will continue its work to ensure the protection of maërl beds, where necessary in cooperation with other competent organisations. This background document may be updated to reflect further developments or further information on the status of the habitat which becomes available.

## Récapitulatif

Le présent document de fond sur les bancs de maërl 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 (Accord OSPAR 2008-6). 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 maërl dans la Liste OSPAR est suivie d'une évaluation des informations les plus récentes sur son statut (distribution, étendue et condition) et des menaces clés, préparée en 2009-2010. Le chapitre 7 fournit des propositions d'actions et de mesures qui pourraient être prises afin d'améliorer l'état de conservation de l'habitat. En se mettant d'accord sur la publication de ce document, les Parties contractantes ont indiqué la nécessité de réviser de nouveau ces propositions. La publication de ce document ne signifie pas, par conséquent que la Commission OSPAR entérine ces propositions de manière formelle. A partir de la nouvelle révision de ces propositions, OSPAR poursuivra ses travaux afin de s'assurer de la protection des bancs de maërl le cas échéant avec la coopération d'autres organisations compétentes. Ce document de fond pourra être actualisé pour tenir compte de nouvelles avancées ou de nouvelles informations qui deviendront disponibles sur l'état de l'habitat.

## 1. Background Information

### Name of habitat

Maërl beds

### Definition of habitat

Maërl 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 maërl requires light to photosynthesize, the depth of live beds is determined by water turbidity, from the lower shore to 40 m or more. Maërl beds may be composed of living or dead maërl or varying proportions of both.

### Correlation with habitat classification scheme

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

**Table 1.** Types of maërl 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 maërl 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
Maërl beds characterised by <i>Phymatolithon calcareum</i> in gravels and sands.	A5.511	SS.SMp.Mrl.Pcal
Upper infralittoral maërl beds characterised by <i>Phymatolithon calcareum</i> in gravels and sand with a wide variety of associated red seaweeds.	A5.511	SS.SMp.Mrl.Pcal.R
Lower infralittoral maërl beds characterised by <i>Phymatolithon calcareum</i> in gravels and sand with a variety of associated echinoderms.	A5.511	SS.SMp.Mrl.Pcal.Nmix
Live maërl beds in sheltered, silty conditions which are dominated by <i>Lithothamnion corallioides</i> with a variety of foliose and filamentous seaweeds.	A5.51	SS.SMp.Mrl.Lcor
Shallow, sheltered infralittoral muddy plains with <i>Lithophyllum fasciculatum</i> maërl.	A5.51	SS.SMp.Mrl.Lfas
Upper infralittoral tide-swept channels of coarse sediment in full or variable salinity conditions with <i>Lithothamnion glaciale</i> maërl 'rhodoliths'.	A5.512	SS.SMp.Mrl.Lgla

Four main species of maërl occur in the OSPAR area, with at least a further six species known to contribute to deposits in certain regions (Table 2). The minor maërl-forming species are endemic to the OSPAR area.

**Table 2.** Maërl-forming species in the OSPAR area

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

### Common characteristics of maërl beds

Maërl beds can build up over millennia to create carbonate-rich gravel deposits that often have high benthic biodiversity and productivity (Hall-Spencer, 1998; Grall *et al.*, 2006; Martin *et al.*, 2006). Maërl growth requires light for photosynthesis. Smothering by fine sediment, lowered oxygen concentrations and the presence of hydrogen sulphide are particularly damaging to maërl-forming algae (Wilson *et al.*, 2004). Maërl beds can harbour high densities of broodstock bivalves and act as nursery areas for the juvenile stages of commercial species of fish, crabs and scallops (Kamenos *et al.*, 2004a,b,c).

## 2. Original Evaluation against the Texel-Faial selection criteria

### List of OSPAR Regions where the habitat occurs

All (I, II, III, IV, V)

### List of OSPAR Regions and Dinter biogeographic zones where the habitat is under threat and/or in decline

There is evidence of threat to maërl beds and their decline in Regions I, II, III, IV and the following Dinter zones; S. Iceland-Faroe Shelf, Boreal, Boreal – Lusitanian, Lusitanian – Boreal, Lusitanian – Cool (see Annex 4).

### Original evaluation against the Texel-Faiel criteria for which the habitat was included on the OSPAR List

**Decline:** A number of studies indicate that maërl beds have declined in both extent and quality in the OSPAR Area. Hall-Spencer & Moore (2000) recorded maërl bed decline off the west coast of Scotland, related to the expansion of the scallop fishing industry there. Similar evidence exists off the Irish coast, where the situation was complicated as species came and went on maërl beds according to seasonal influences. Extraction of both living and fossil deposits have depleted beds in the Fal estuary in England and at least four maërl beds in Brittany have been completely destroyed by extraction (Hily & Le Foll, 1990; Hall-Spencer, 1995).

Most Breton maërl beds are affected by human activities and the only pristine grounds remaining are small compared to the extensive maërl beds that covered several square kilometres in the 1960s (Grall & Hall-Spencer, 2003). For example, one of the largest maërl beds in Brittany (Glenan) was covered in living maërl until maërl extraction started 35 years ago. When surveyed in 1999 live maërl 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 Breton's extensive maërl beds have disappeared, not only because of extraction but also because of sewage discharge (Grall & Glémarec, 1997).

A review of historical data and the current situation at a maërl bed on the west coast of Scotland (Firth of Clyde) has revealed extensive changes over the last 100 years. A living maërl bed with abundant large thalli and nests of the gaping file shell *Limaria hians* has become a bed of predominantly dead maërl with few, small, live thalli and no *L. hians* (Hall-Spencer & Moore, 2003).

**Sensitivity:** The three commonest species of maërl are very sensitive to substrata loss, smothering, increase in suspended sediment, abrasion and physical disturbance which can prevent light reaching the living maërl and therefore halt photosynthesis (Jones et al., 2000). The impacts of any damage to maërl beds are long lasting because the key habitat structuring species has a very poor regenerative ability (Hall-Spencer & Moore, 2003). Extremely slow growth rates for maërl have been recorded in data from Ireland, England, France, Norway, Scotland and Spain. These are of the order of tenths of millimetres to one millimetre per year (Bosence & Wilson, 2003).

Maërl beds in the Sound of Iona are recorded as containing dead nodules up to 4000 years old (Farrow, 1983, cited in Maggs et al., 1998). Adey (1970) estimates the life-span of individual plants of *L. glaciale* to be from 10-50 years and 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.

**Ecological significance:** Maërl beds are an important habitat for a wide variety of marine animals and plants which live amongst or are attached to the nodules, or which burrow in the coarse gravel or fossil maërl 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 maërl habitat or rarely found elsewhere. Dead maërl also has an ecological importance, supporting diverse communities, although these have been reported to be less rich than those which in live maërl beds (Keegan, 1974). Both dead and living maërl deposits are also considered to be an important source of subtidal and beach-forming calcareous sediments (Farrow et al., 1978).

Maërl 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 maërl deposits in Ireland and scallops on maërl 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).

**Threat:** In Europe, maërl 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, maërl is considered to be a non-renewable resource and, even if the proportion of living maërl in commercially collected material is low, extraction has major effects on the wide range of species present in both live and dead maërl deposits (Hall-Spencer, 1998; Barbera et al., 2003)

As well as the direct effect of the physical removal of the maërl 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 maërl 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 maërl 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, BIOMAËRL 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 maërl beds but it has since become an impoverished muddy sand community. In 1969 the habitat was described as a clean maërl 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).

**ICES evaluation:** The Leiden Workshop concluded that evidence for the decline and threat of maërl beds was “strong” over the whole OSPAR area. In their review of the nomination for this habitat, ICES agreed that evidence for decline and threat of this habitat was sufficient, but only for OSPAR Region III (ICES, 2002). Results from a four-year EC funded project have since been published (BIOMAËRL, 2003) and show that both the threat to maërl beds and their decline is more widespread. Maërl beds are therefore still nominated for the entire OSPAR area.

### 3. Current status of the habitat

#### Distribution in OSPAR maritime area

Maërl beds have a patchy distribution in the OSPAR area and are recorded in 96 fifty-km squares (Fig. 1). There are unpublished reports of maërl in fjordic locations off Greenland and Spitzbergen. This habitat is patchily distributed but widely recorded from Scandinavia (Adey & Adey, 1973; King & Schramm, 1982; Freiwald & Henrich, 1994; Husa *et al.*, 2004) to Portugal and the Azores (Peña & Bárbara, 2007). Maërl is particularly abundant on the west coasts of Scotland, Ireland, Brittany and in the rias of Galicia in Spain (Adey & McKibbin, 1970; Cabioch 1970; Birkett *et al.*, 1998; Hall-Spencer *et al.*, 2006; Grall *et al.*, 2006). Annex 1 provides detailed maps of these key areas. Maërl beds

typically occur in depths of <40 m and can extend onto the lower shore. The deepest maërl beds in the OSPAR area are likely to occur around Madeira and the Canary Islands (E. Soler-Onis, personal communication).

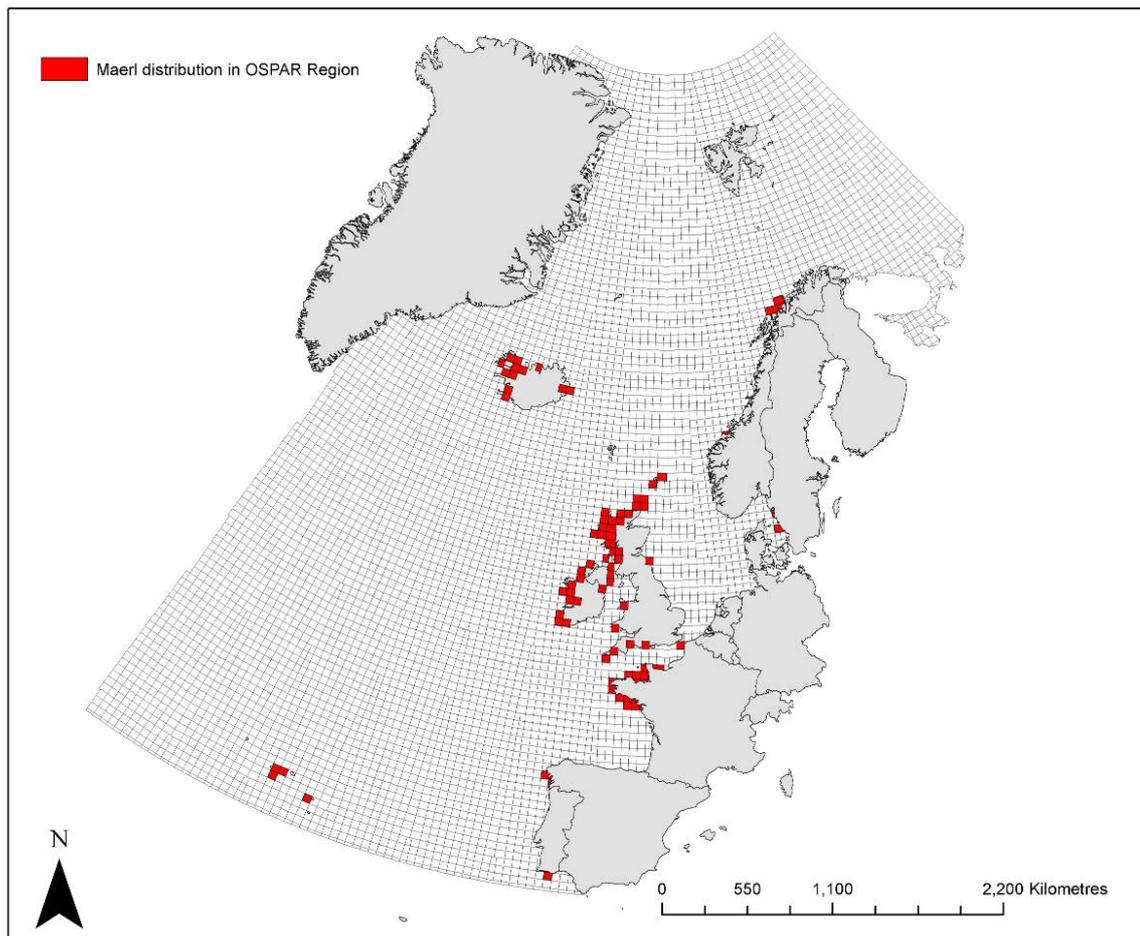


Figure 1: Distribution of 50 km squares containing maërl beds in the OSPAR maritime area (based on data for Galicia supplied by Viviana Peña Freire and Ignacio Bárbara, for Brittany by Jacques Grall, the UK National Biodiversity Network for the UK, NPW and EHS for Ireland, Estibaliz Berecibar and Rui Santos for Portugal, and Karl Gunnarson for Iceland; other records collated by Emma Jackson and Jason Hall-Spencer at the University of Plymouth). The Norwegian records are incomplete. Note that maërl may occupy only a small area within a grid square; one of the UK's database records (N Wales) may refer to very small quantities of maërl and the SE Scotland record is queried here.

### Extent

Maërl beds that have been mapped in the UK, Ireland, Brittany, Galicia and the Algarve (Annex 1) vary from tens to thousands of square metres with reductions in extent recorded in all of these areas. In the UK, large maërl beds in the Sound of Arisaig were mapped using acoustic surveys backed up with biological sampling (Davies & Hall-Spencer, 2005). Similar methods were used off Antrim, Northern Ireland, and revealed that maërl beds occupied a total area of approximately 7 km<sup>2</sup> (Wilson *et al.*, 2007). Off Swanage in England maërl occurs between 11-23 m below chart datum in areas with current velocities of 37-80 cm/s (Mitchell & Collins, 2004). De Grave (1999) mapped eight areas of maërl in Ireland totalling 60 km<sup>2</sup> (De Grave *et al.*, 2000) and DEHLG in Ireland have since mapped additional beds (Annex 1). In France, Breton maërl beds that covered several square kilometres in the 1960s have been reduced in extent by extraction and eutrophication (Grall & Hall-Spencer, 2003). In

Spain, maërl covers 14 km<sup>2</sup> in the Ria de Arousa where several beds have >90% live maërl cover; the total estimate for all of the rias in Galicia is 23.5 km<sup>2</sup> (Annex 1).

### Condition

Maërl beds have undergone well-documented declines in condition and are being removed for commercial use in Regions I, II, III and IV whereas Region V has no reported impacts. Scallop dredging, construction projects and fish-farming currently impact certain maërl beds in the UK (Hall-Spencer & Moore, 2000a,b; Hall-Spencer *et al.*, 2006; Camplin, 2007; Hall-Spencer & Bamber, 2007) but commercial extraction of this habitat was discontinued in 2005 (Hall-Spencer, 2005). Irish maërl beds are generally considered to be in good condition but some are deteriorating due to commercial extraction, mariculture, demersal fishing and the localized effects of boat mooring chains (Vize, 2005). Many Breton maërl grounds have been permanently impacted by commercial extraction and their ecology is altering due to eutrophication and invasive species such as *Crepidula fornicata* although monitoring over the past decade has shown that better management of agricultural and urban/industrial effluent has improved quality in the Bay of Brest (Grall & Glémarec, 1997a,b; Grall & Hall-Spencer, 2003). In Galicia ongoing deterioration in maërl bed condition is due to mussel farming which kills maërl through increased sedimentation, reducing habitat complexity and lowering biodiversity (Peña & Bárbara, 2007a,b). Few maërl beds are protected in the OSPAR area so further declines in their condition are expected over the next decade due primarily to commercial extraction, mariculture and demersal fishing activities.

### Limitations in knowledge

There are scant data on maërl beds in OSPAR Regions I and V although this habitat is likely to be widespread in Norway. Mariculture and demersal fishing activities probably affect maërl beds throughout Region I.

## 4. Evaluation of threats and impacts

**Relevant human activity:** Extraction of sand, stone and gravel, construction, land-based activities, 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.

**Global and Regional importance:** Maërl beds occur from the tropics to polar waters (Foster 2001; Hinojosa-Arango & Riosmena-Rodriguez, 2004) and form productive communities in the OSPAR area (Martin *et al.*, 2005, 2007a). Both dead and living maërl beds are important sources of subtidal and beach-forming calcareous sediments (Bosence & Wilson, 2003; Martin *et al.*, 2007b) and contribute to the pH balance of seawater (Canals & Ballesteros, 1997). Maërl beds harbour high biodiversity and can benefit commercial fisheries because they can contain broodstock bivalves and act as nursery areas for juveniles of commercial species (Hauton *et al.*, 2003; Hall-Spencer *et al.*, 2003; Kamenos *et al.*, 2004a,b,c).

**Rarity:** Maërl is absent off Belgium, the Netherlands, Germany and Sweden and is rare off Denmark and England. Maërl is patchily distributed but widespread along the west coasts of Norway, Scotland and Ireland and is also recorded at numerous locations around Brittany, Galicia and the Algarve. There is insufficient information at present on the distribution of maërl to determine its rarity around Greenland, Iceland, the Faroes, Portugal and the Azores.

**Sensitivity:** Maërl is very sensitive to substratum loss, smothering, increase in suspended sediment, abrasion and physical disturbance, which can prevent light reaching the living maërl and therefore halt photosynthesis (Jones *et al.*, 2000). Maërl beds are vulnerable as maërl thalli grow extremely slowly, forming habitats that are thousands of years old (Adey & McKibbin, 1970; Potin *et al.*, 1990; Bosence & Wilson, 2003; Blake & Maggs, 2003; Grall & Hall-Spencer, 2003). The “recovery potential” of maërl beds has been categorized by OSPAR as ‘poor’ meaning that only partial recovery is likely within 10 years and full recovery may take up to 25 years (IMPACT, 1998). Maërl recovery may never occur if a bed is removed by dredging or completely smothered by sediment.

**Ecological significance:** As well as providing reserves of commercial broodstock and forming important nursery areas for commercially valuable species, maërl beds also form isolated habitats of high benthic biodiversity and biomass (Grall & Glémarec, 1997a,b; Hall-Spencer, 1998; BIOMAËRL, 1999; Hall-Spencer *et al.*, 2003; Steller *et al.*, 2003). Some maërl beds, including dead beds, 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, 2007a,b).

**Decline:** The greatest decline in maërl habitat appears to have occurred in Brittany where maërl extraction is ongoing and has led to the demise of the most extensive maërl beds (Grall & Hall-Spencer, 2003). Extraction of living and fossil deposits has depleted beds in the Fal estuary in England where maërl extraction was banned in 2005 (Hall-Spencer, 2005). Extraction of maërl from a single bed in Iceland has taken place for the last two years, at a rate of approx. 10 000 m<sup>3</sup> p.a (K. Gunnarson, pers. comm.). Hall-Spencer & Moore (2000a,b) recorded declines in maërl habitat off the west coast of Scotland due to scallop dredging over the past 100 years, and some beds have less than 25% live thalli. Mariculture has also contributed to the decline of maërl habitat in Ireland, Scotland and Galicia (Hall-Spencer *et al.*, 2006; Peña *et al.*, 2006, Peña & Bárbara, 2007a,b). In Galicia, Peña & Bárbara (2007a,b) found that most of the well-preserved maërl beds were in protected areas such as the Islas Atlánticas National Park, or restricted to shallow areas less than 9 m depth where mussel rafts could not be stationed.

**Threat:** Maërl is dredged for various purposes. In the 1970s a peak of around 600 000 tonnes were extracted per year in France (Briand, 1991). Extraction is ongoing in Iceland, Ireland and France and has major effects on the species present due to the direct effect of habitat removal and impacts from increased sediment loads which smother surrounding communities (Hall-Spencer, 1998; De Grave & Whittaker, 1999; Barbera *et al.*, 2003). Maërl beds are also threatened by the use of demersal fishing gear, most notably scallop dredges and suction dredges in UK and Irish waters (Hall-Spencer & Moore, 2000a,b; Hauton *et al.*, 2003), and by mariculture activities that pollute the seabed in Spain, France, Ireland, the UK and probably Norway (Barberá *et al.*, 2003; Wilson *et al.* 2004; Hall-Spencer *et al.*, 2006; Peña *et al.*, 2006; Hall-Spencer & Bamber, 2007). Coastal construction and sewage may also impact maërl beds through increased sediment loads and/or the stimulation of excessive growth of ephemeral species of macroalgae (Birkett *et al.*, 1998; De Grave *et al.*, 2000; Grall & Hall-Spencer 2003).

Global ocean models predict surface pH reductions of 0.3-0.5 units by the year 2100 due to the uptake of anthropogenic CO<sub>2</sub> (Caldeira & Wickett, 2005). This is likely to have strong negative impacts on coralline algae (Hall-Spencer *et al.*, 2008; Martin *et al.*, in press) although no research has been carried out on the effects of ocean acidification on maërl beds in the OSPAR region. Ocean warming could also have particularly severe effects on some maërl species due to their fragmented ranges and poor dispersal but only limited knowledge of temperature tolerances and optima are available for some species of maërl (Blake & Maggs, 2004).

## 5. Existing Management measures

There are no protective management measures in place for maërl beds in Iceland and Norway. The EU Habitats Directive requires Member States to take appropriate management measures to ensure that any exploitation is compatible with maërl being maintained at a favourable conservation status. Two maërl-forming species, *Lithothamnium corallioides* and *Phymatolithon calcareum*, are listed in Annex V of the Habitats Directive and in some locations maërl 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. Maërl is included as a key habitat for Ireland and the UK within the Annex I habitats 'large shallow inlet and bays' 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 maërl beds. However, there is incontrovertible evidence that existing management measures are failing to protect many of the maërl beds in EU waters.

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

The main requirement is for accurate mapping so that Marine Spatial Planning can be used to protect maërl beds. In Scotland, for example, SNH has provided information on the location of maërl beds to help developers avoid placing sewage outfalls in their vicinity (D. Donnan, pers. comm.). 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 shellfish fisheries, e.g. in the Sound of Arisaig, can refer to maërl ([www.soundofarisaig.org](http://www.soundofarisaig.org)). 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).

## 6. Conclusion on overall status

Commercial dredging of maërl deposits in OSPAR Regions I, II and III is particularly destructive since this removes the productive surface layer and dumps sediment on any live thalli that escape dredging, inhibiting habitat recovery. The cessation of extraction licences in the UK is an important step as the level of damage that can result from extraction is clearly seen in Brittany. Fishing activities are known to be causing ongoing damage to these habitats in OSPAR Regions II and III where scallop dredging reduces the complexity, biodiversity and long-term viability of these habitats. Sewage pollution has been directly linked to the loss of maërl beds in the Bay of Brest but improved water quality has allowed the recovery of certain beds over the past decade – as sewage treatment improves the negative effects on maërl beds are likely to diminish. The increased pressure of mariculture on sea lochs in OSPAR Regions I and III and in the rias of OSPAR Region IV has led to ongoing impacts on maërl beds. Three factors may mitigate against the continued decline of NE Atlantic maërl beds: (1) increased regulation of various marine activities; (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.

## 7. Action to be taken by OSPAR

### **Action/measures that OSPAR could take, subject to OSPAR agreement**

As set out in Article 4 of Annex V of the Convention, OSPAR has agreed that no programme or measure concerning a question relating to the management of fisheries shall be adopted under this Annex. However where the Commission considers that action is desirable in relation to such a question, it shall draw that question to the attention of the authority or international body competent for that question. Where action within the competence of the Commission is desirable to complement or support action by those authorities or bodies, the Commission shall endeavour to cooperate with them.

As noted above, in Galicia well-preserved maërl beds in deeper water are mostly confined to protected areas such as the Islas Atlánticas National Park (Peña & Bárbara 2007a,b). Where appropriate, further protection of maërl beds within national, EU (Habitats Directive) or OSPAR marine protected areas should be considered. Where maërl beds already occur within designated sites, management systems may need improvement to ensure adequate protection of the habitat. The feasibility of temporarily re-locating maërl in Milford Haven during construction of jetties was considered but it was thought impractical (Camplin, 2007).

### **Brief summary of the proposed monitoring system (see annex 2)**

To improve understanding of the state of maërl beds and to follow any changes over time it is important to establish suitable long-term monitoring of the distribution, extent and quality of these habitats and to assess the effectiveness of any management measures put in place. The monitoring program should be targeted at the site-specific threats to the habitat. Under OSPAR, any maërl beds in MPAs and SACs should be monitored to assess condition, and a report be compiled, at intervals of a recommended minimum frequency of six years. The features that need to be monitored are

- extent of bed
- percentage of live maërl
- a measure of biodiversity (possible measures are discussed below in Annex 2)
- physical data (e.g. water temperature, turbidity)
- chemical data (e.g. N, P values to determine possible eutrophication)

## Annex 1: Overview of data and information provided by Contracting Parties<sup>3</sup>

**Distribution on the Atlantic coast of France:** French maërl 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 maërl bed communities and distinguished them from other types of gravel shown on sedimentary maps of the area. The total number of Breton maërl beds (Fig. 2) is currently undergoing assessment; they can be small (10–100 m<sup>2</sup>) and are therefore difficult to map. However, Gautier (1971) recorded at least 70 maërl beds >1 km<sup>2</sup> from around 17 bays and islands in the region. Other extensive beds are those of Belle-Ile, Bay of Concarneau, Glénan, the Bay of Brest and the Bay of Morlaix. Numerous smaller maërl beds occur within the complex coastline off Brittany, some of them having been discovered recently.

On Atlantic coasts of France, maërl is distributed mainly around the coasts of Brittany. A few maërl beds have been recorded in the eastern part of the Channel, but reports need to be confirmed. Maërl is absent from the southern Bay of Biscay from the Loire estuary to the basque country. The largest concentration of maërl in the western Channel occurs around the Chausey archipelago, with numerous extensive beds distributed in the shallow western and southern part of these islands.

The species composition of the bank varies according to the biotope (see section 1). Of the two dominant species, *Phymatholiton calcareum* occurs in 'open' areas, and *Lithothamnion corallioides* is found in more semi-enclosed bays and inlets, but in general both species grow together. There is a *Lithophyllum dentatum* bed in the eastern part of the Bay of Brest.

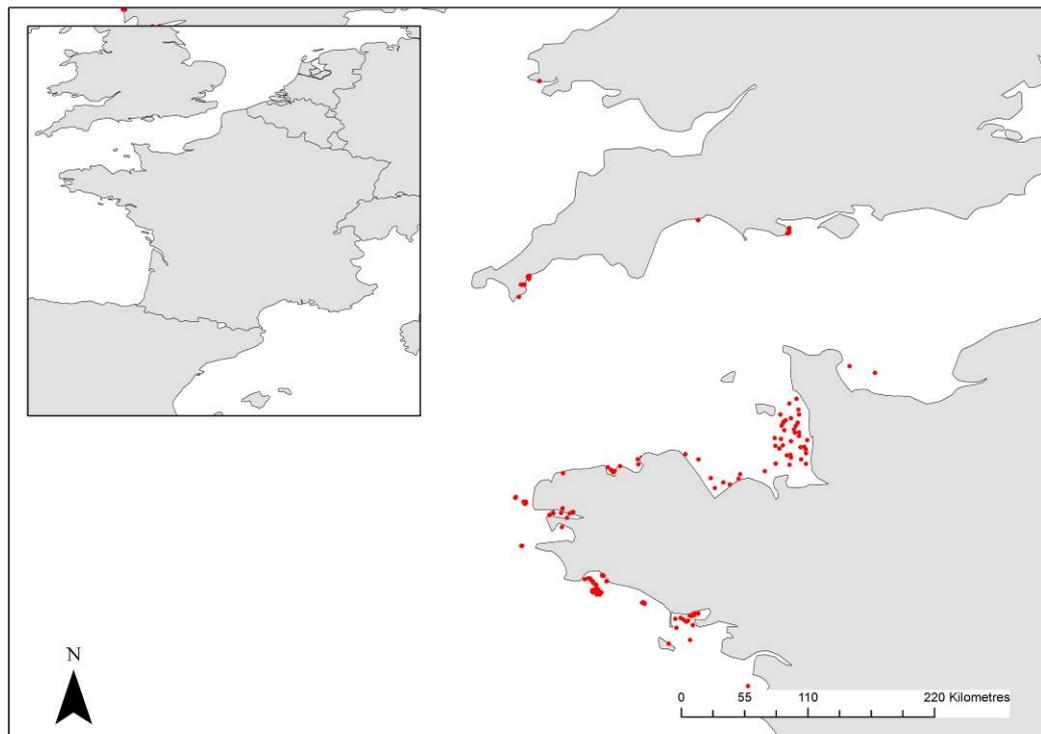


Figure 2. Map showing the location of maërl beds in Brittany, England and south Wales. Data for Brittany supplied by Jacques Grall.

<sup>3</sup> Maërl was nominated for inclusion in the OSPAR List in 2001 by France and UK

In the 1960s Breton maërl beds covered several square kilometres, the largest being the Glénan bed. Dredging has seriously impacted the extent of this maërl bed, however (see section 3.3). Some maërl beds that 30 years ago would have appeared in Table 3 are not mentioned since they have been entirely destroyed. Only a few beds (e.g. Glénan, Trevignon) have recently been mapped in France with accurate acoustic methods. However, despite considerable heterogeneity in the mapping methods, Table 3 provides data for live maërl/dead maërl 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 in maërl extent over time, including how live maërl was totally removed from the northern Glénan 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 maërl left deep trenches. On the other hand, repeated surveys in the northern basin of the Bay of Brest show that management of urban effluents has allowed an increase in live maërl cover over a 15-year period.

**Table 3.** Surface area (ha) of live, dead, unknown (to be reassessed) of the main French maërl beds

Sites	Live maërl	Dead Maërl	Unknown maërl	Heterogeneous sediments (including Total maërl)	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
<b>Golfe Normandy-Breton</b>	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
<b>Entrance of Golfe du Morbihan</b>	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

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

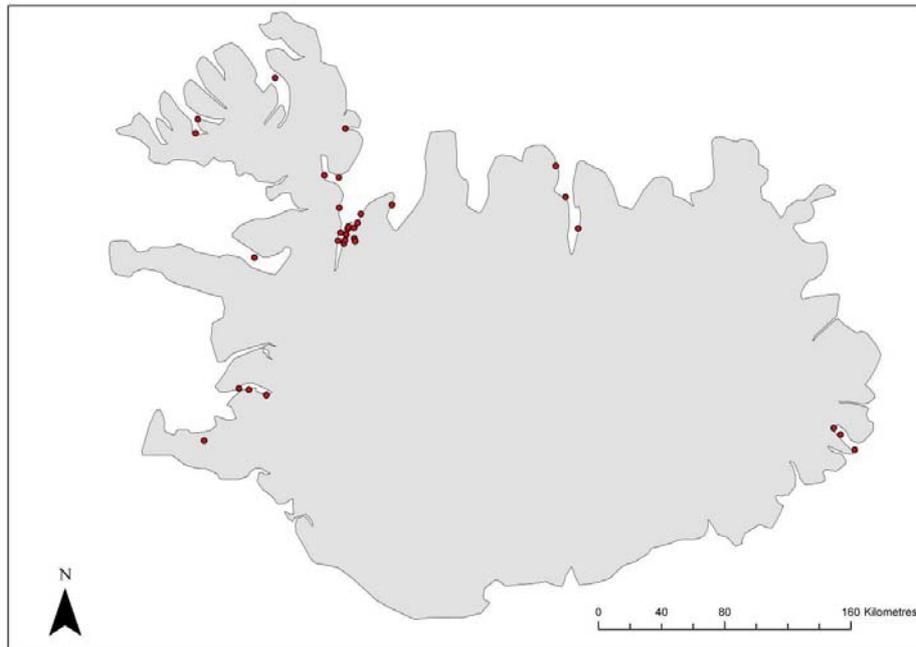


Figure 3. Known distribution of maërl habitats in Iceland (from various datasets including personal communications from Karl Gunnarsson, Reykjavik and Ken Collins, Southampton).

**Distribution in Ireland:** Maërl is widely distributed in the mid-west and the southwest of Ireland (Figure 1). The minimum number of maërl beds in Irish waters is estimated to be 35-40, with the majority (c. 65-70%) in Galway Bay and along the Connemara coastline (De Grave & Whitaker, 1999), ranging from 0.5 to 15 m below chart datum (De Grave, 1999). The majority of the maërl beds are located between 0 and 20 m with the exception of one off Inishman found in depths of 20 to 30 m (M. Guiry, pers. comm.). De Grave (1999, his table 3) gives the area of the bed at Inishman as 4 km<sup>2</sup>, Mannin as 2 km<sup>2</sup>, and Eastern Galway Bay as 20 km<sup>2</sup>; the paper acknowledges that Kilkieran Bay, Co. Galway, which was not mapped, has some of the largest deposits. De Grave (1999) mapped eight areas and indicated that 60 km<sup>2</sup> of seabed was occupied by maërl (De Grave *et al.*, 2000). Since then, DEHLG have mapped an additional four beds (Kingstown Bay, Clew Bay, Kilkieran Bay/Greatman's Bay, Valentia Harbour) in detail as part of an ongoing maërl mapping programme. They also mapped Kenmare Bay using broadscale mapping c. 6 years ago. Remote sensing surveys in Counties Clare (1 bed), Cork (8 beds), Co. Galway (11 beds) and Kerry (2 beds) indicated that 37.46 km<sup>2</sup> of seabed was occupied by maërl (De Grave *et al.*, 2000) and it was considered that another 20 km<sup>2</sup> 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 (Figure 4).



Figure 4. Distribution of some mapped beds of live and dead maërl) on mid-west coast of Ireland, with inset showing position of coastline. Distribution mapped by DEHLG (Ireland).

**Distribution on Atlantic coasts of Portugal:** Information is sparse but maërl beds are known only from the Algarve (Figure 5).

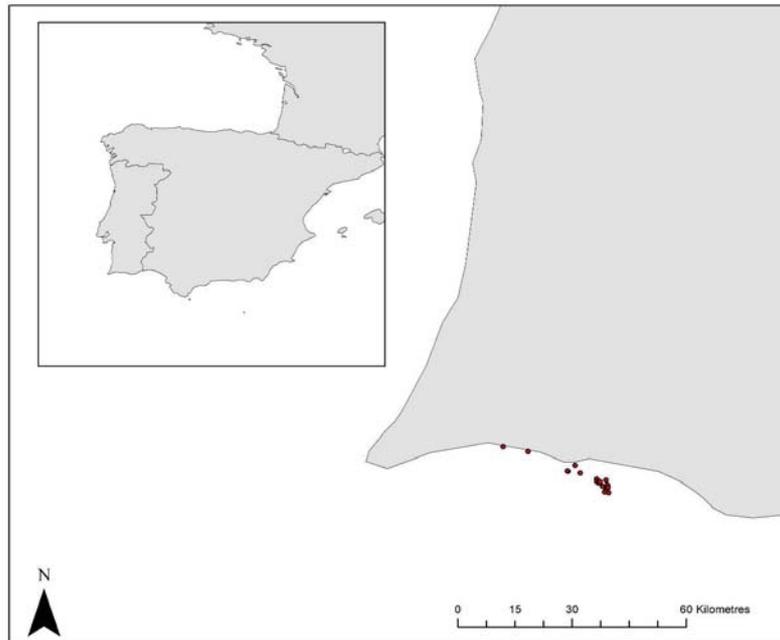


Figure 5. Distribution of maërl habitats on southern (Algarve) coast of Portugal from data supplied by Estibaliz Berecibar and Rui Santos (inset, map of the Iberian Peninsula).

**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.* (2004, 2006) and Peña & Bárbara (2007a,b) have reported work in progress on the distribution and ecology of maërl beds off the Atlantic coast of Spain and show that maërl habitat is mainly distributed in the rías (Fig. 6). It is most widespread in the Ria de Arousa where maërl 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) although recent studies confirm the occurrence of *Mesophyllum* sp. as a maërl-forming species in one shallow maërl bed in the Ría de Arousa (V. Peña, personal communication). Maërl is estimated to cover 14 km<sup>2</sup> in the Ria de Arousa (Table 4) where several beds have >90% live maërl cover; the total estimate for all the rías is 23.5 km<sup>2</sup> (Table 4).

Table 4. Extent of maërl beds in Galicia, Spain (from Peña &amp; Bárbera, 2007b)

Maërl bed regions	Number of beds previously known in region	Present known number of beds	Estimated surface area occupied (km <sup>2</sup> )
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
<b>Total</b>	<b>67</b>	<b>108</b>	<b>23.45</b>

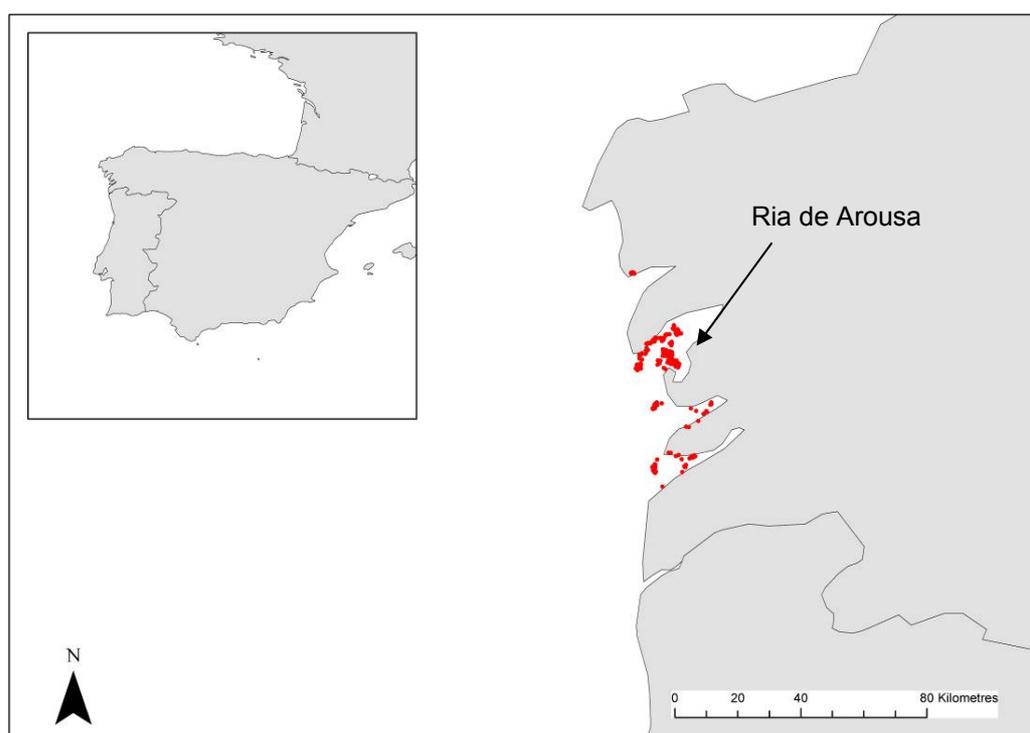


Figure 6. Distribution of maërl habitats in Galicia, NW Spain (inset, map of the Iberian Peninsula). It is most common in the Ria de Arousa (data from Peña & Bárbera, 2007a).

**Distribution in the UK:** The distribution of maërl around the coasts of the UK is patchy, with the majority of records from the fjordic coastline of western Scotland (Fig. 7). Maërl 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. Maërl is absent from the east coast of mainland Scotland (the single record from SE Scotland is questionable). In England, maërl beds are rare (Fig. 2). In Cornwall there is an extensive bed of live maërl growing on the St. Mawes Bank in the Fal estuary (Farnham & Bishop, 1985). Maërl 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 maërl beds off the Dorset coast have been mapped (Fig. 7; Mitchell & Collins, 2004). In Wales, limited and patchy maërl 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). Relatively small maërl beds occur off the open coast of Northern

Ireland in Antrim (Fig. 8) and in the sealoughs, particularly Strangford Lough. Irvine & Chamberlain (1994) report that *Phymatolithon calcareum* forms maërl at sites from Dorset to Shetland along the western coasts of the UK whereas maërl-forming *Lithothamnion glaciale* has a northern distribution in the UK and *Lithothamnion corallioides* is restricted to the southwest.

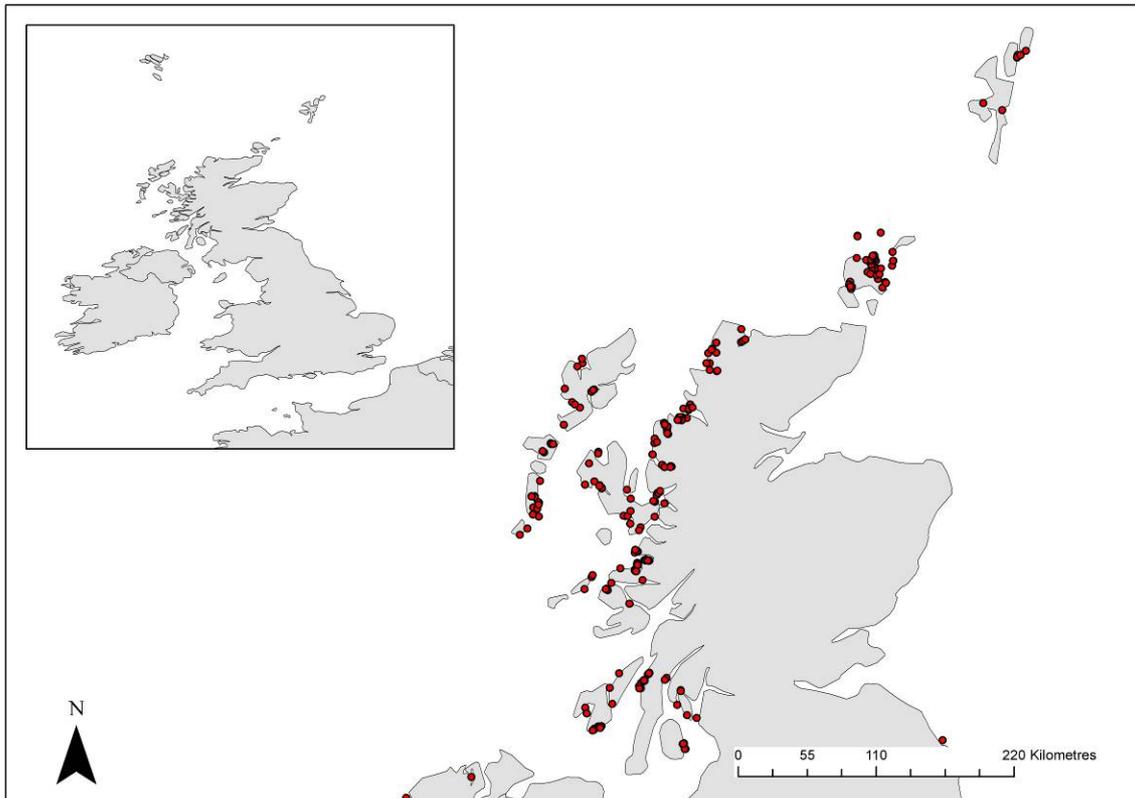


Figure 7: Map showing the locations of recorded maërl beds in Scotland (and extreme north of Ireland; data provided by NBN). Note that symbols represent the approximate locations of maërl beds and not their extent. Inset, coastline of Britain and Ireland.

A few maërl beds in the UK have been mapped with some precision, although the total area of maërl occupied is rarely reported. In England the first studies of maërl 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. 8) made detailed maërl surveys off Swanage in Dorset using pipe dredge and diver surveys, involving collecting all live maërl from 0.5 m<sup>2</sup> quadrats placed on the seabed, weighing it, and analysing the data with GIS. The maërl density data were presented so that they spanned the entire maërl bed area. Physical parameters were correlated with the maërl distribution. Maërl distribution occurred only within a certain depth range, 11.3 m (below chart datum) to 22.6 m. Comparison of near-bed current velocities plotted against maërl densities for each transect showed maërl to be absent at velocities lower than 37 cm/s and above 80 cm/s.

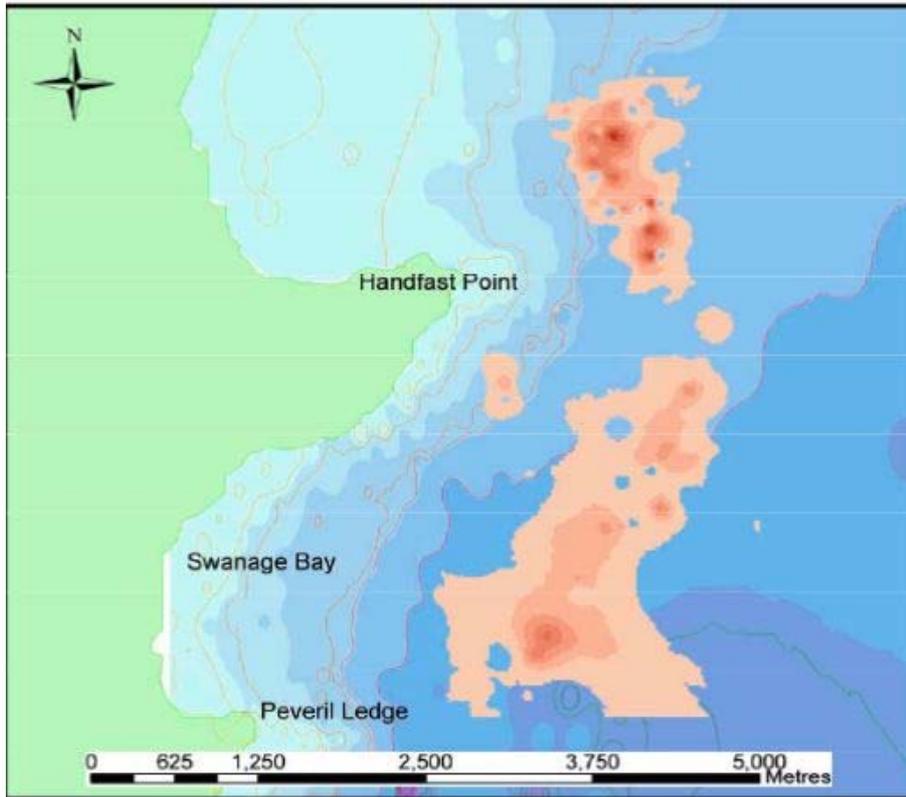


Figure 8. Maërl bed off Swanage, Dorset (reproduced from Mitchell & Collins, 2004).



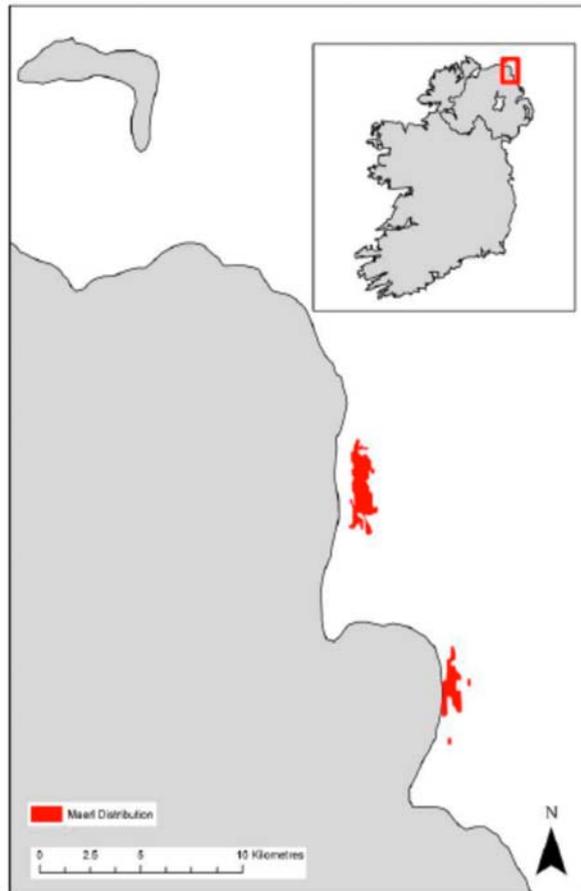


Figure 9. Beds off the coast of Antrim, Northern Ireland, UK

Beds off the coast of Antrim, Northern Ireland, UK (Fig. 9), occupy a total area of approximately 7 km<sup>2</sup> (Wilson *et al.*, 2007).

In Wales, a study in 2005 mapped the extent, density, and ratio of live versus dead thalli to establish the baseline for monitoring the maërl bed in the Milford Haven Estuary. The results of the study showed the bed to be approximately 1.5 square kilometres, of which 0.5 square kilometres contained live maërl (Bunker & Camplin, 2005).

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 maërl 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 maërl 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. 10). Data were collected using acoustic survey techniques backed up with biological sampling (Davies & Hall-Spencer, 2005).

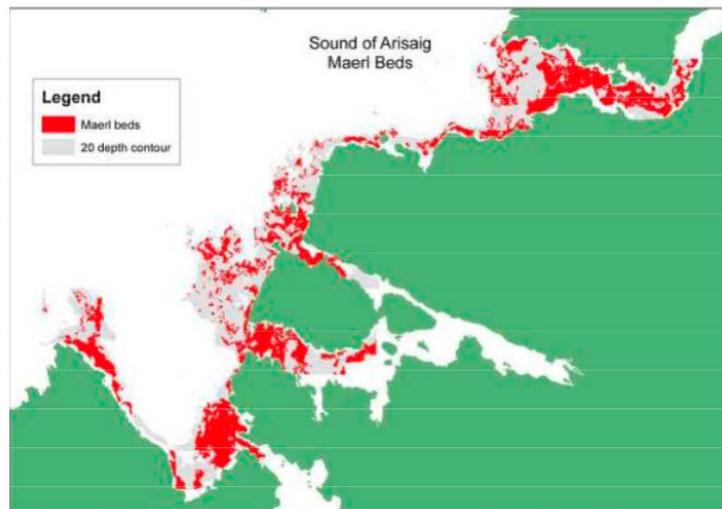


Figure 10. Distribution of maerl beds and sand banks in the Sound of Arisaig (Davies & Hall-Spencer 2005).

## Annex 2: Detailed description of the proposed monitoring and assessment strategy

There is no evidence in the literature of maërl beds having been repeatedly surveyed except in relation to impact studies (Perrins *et al.*, 1995; Hall-Spencer & Moore, 2000a, b). No time-series studies on maërl beds were identified in the UK by Hiscock & Kimmance (2003). In Brittany, 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). 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.

### Development of new monitoring programmes

In order to better understand the state of maërl 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 maërl beds, their key threats, and the effectiveness of any conservation measures put in place. The approach to monitoring of each maërl 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 targeted at the threat, and its potential impact so that impacts will be detected if they occur.

Under OSPAR, any maërl 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 maërl beds. The features that need to be monitored are

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

### Mapping of maërl beds and determination of live/dead maërl

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 maërl 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. Maërl 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 maërl beds where beds are thick and extensive, providing they are used with adequate ground-truthing. However, often maërl 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 maërl is live or dead. Given that many living maërl beds are found in association with subfossil beds that died 1000-8000 years ago, determining the amount of live maërl 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 maërl, 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 maërl, 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 (Figure 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 maërl, or the abundance of live maërl, as a proxy for the biota of maërl 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 maërl with the effects on the biota (various measures of invertebrate and algae diversity and abundance). In addition to this, the three-dimensional structure of maërl beds (i.e. depth of live and dead maërl deposits) has potential as an indication of the condition of the bed. In Brittany, reduction in the depth of maërl deposits has had obvious impacts on the biodiversity of maërl beds.



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

## Measures of biodiversity for monitoring maërl beds

As maërl 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 maërl 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 maërl beds, is a suite of small red algae that are more or less confined to maërl. *Cruoria cruoriaeformis*, *Halymenia latifolia* and *Gelidiella calcicola* are found on maërl beds in Britain, Ireland, Brittany 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 the UK's 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 maërl biota is taken into account in analysing the results. During monitoring of the impact of nearby civil engineering work on maërl 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 BIOMAËRL (P.G. Moore, pers. comm.). The diversity of the polychaete *Hesiono 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 maërl 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. Maërl 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 maërl 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.

## Annex 3: References

- Aðalsteinsdóttir, K. and Gardarsson, A. (1980) Botndýralíf í Hvalfirði. Lífæðisofnun Háskólans Fjölrit nr.14, Reykjavík 1980, 167 pp.
- Adey, W.H. & Adey, P.J. (1973). Studies on the biosystematics and ecology of the epilithic crustose Corallinaceae of the British Isles. *British Phycological Journal* 8: 343–407.
- Adey, W.H. & McKibbin, D.L. (1970) Studies on the maërl species *Phymatolithon calcareum* (Pallas) nov. comb. and *Lithothamnion corallioides* Crouan in the Ria de Vigo. *Botanica Marina* 13:100–106.
- Bárbara, I., Cremades, J. & Veiga, A.J. (2004). Floristic study of a maërl and gravel subtidal bed in the 'Ría de Arousa' (Galicia, Spain). *Botanica Complutensis* 28: 27-37.
- Bárbara, C. et al., (2003) Conservation and mangagement of northeast Atlantic and Mediterranean maërl beds. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13: S65-S76.
- Bárbara, I., Díaz, P., Cremades, J., Peña, V., López-Rodríguez, M.C., Bercibar, E. & Santos, R. (2006). Catálogo gallego de especies amenazadas y lista roja de las algas bentónicas marinas de Galicia. *Bol. Inf. Soc. Esp. Ficol.* 35: 9-19.
- BIOMAËRL (1999). Final Report, BIOMAËRL project (Coordinator: P.G.Moore, University Marine Biological Station Millport, Scotland), EC Contract No. MAS3-CT95-0020, 1: 1–541, 2: 542-973 pp. + Appendix.
- BIOMAËRL team (2003). Conservation and management of N.E Atlantic and Mediterranean maërl beds. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13 (S1): 65-76.
- Birkett, D.A., Maggs, C.A., & Dring, M.J. (1998). Maërl (volume V). An overview of dynamic and sensitivity characteristics for conservation management of marine SACs. Scottish Association for Marine Science (UK Marine SACs Project). 116 pp.
- Blake, C. & Maggs, C. A. (2003). Comparative growth rates and internal banding periodicity of maërl species (Corallinales, Rhodophyta) from northern Europe. *Phycologia* 42: 606-612.
- Blunden, G. et al. (1977). The composition of maërl from the Glenan Islands of Southern Brittany. *Botanica Marina* 20: 121–125.
- Bosence, D. & Wilson, J. (2003) Maërl growth, carbonate production rates and accumulation rates in the northeast Atlantic. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13:S21-S31.
- Bunker, F. St P. D. and Camplin M. D., 2007. A study of the Milford Haven maërl bed in 2005 using drop down video and diving. A report to the Countryside Council for Wales by Marine Seen. CCW Contract Science Report 769. Countryside Council for Wales, Bangor, 174pp + iii.
- Cabioch, J. (1970). Le maërl des côtes de Bretagne et le problème de sa survie. *Penn ar Bed* 7: 421-429. Cabioch, J. (1969). Les fonds de maërl de la baie de Morlaix et leur peuplement végétal. *Cahiers de Biologie Marine* 10: 139–161.
- Cabioch, L. (1968). Contribution à la connaissance des peuplements benthiques de la Manche occidentale. *Cahiers de Biologie Marine* 9 (5 suppl.), 493–720.
- Cadée, G.C. 1968. Molluscan biocoenoses and thanathocoenoses in the Ría de Arosa, Galicia, Spain. *Zoologische Verhandelingen* 95: 1-46.

- Caldeira, K. & Wickett, M. E. 2005 Ocean model predictions of chemistry changes from carbon dioxide emissions to the atmosphere and ocean. *J. Geophys. Res.* 110, C09S04.
- Camplin, M. (2007). Monitoring the impact of civil engineering works on maërl in Milford Haven. Abstracts, Countryside Council for Wales Marine and Freshwater Workshop 2007.
- Canals, M. & Ballesteros, E. (1997). Production of carbonate particles by phytobenthic communities on the Mallorca-Menorca shelf, northwestern Mediterranean Sea. *Deep-Sea Research II* 44: 611-629.
- Clark, R.N. (2000) The chiton fauna of the Gulf of California rhodolith beds (with descriptions of four new species). *Nemouria: Occasional papers of the Delaware Museum of Natural History* 43: 1-19.
- Davies, J. & Hall-Spencer J.M. (2005) Mapping of the benthic biotopes in the proposed Sound of Arisaig Special Area of Conservation. *Scottish Natural Heritage Research and Surveying Report No 83.*
- De Grave, S. (1999). The influence of sedimentary heterogeneity on within maërl bed differences in infaunal crustacean community. *Estuarine, Coastal and Shelf Science* 49: 153-163.
- De Grave, S. & Whitaker, A. (1999a). A census of maërl beds in Irish waters. *Aquatic Conservation: Marine and Freshwater Ecosystems* 9: 303-311.
- De Grave, S. & Whitaker, A. (1999b). Benthic community re-adjustment following dredging of a muddy maërl matrix. *Marine Pollution Bulletin* 38 (2), 102–108.
- De Grave, S., Fazakerley, H., Kelly, L., Guiry, M.D, Ryan, M., & Walshe, J. (2000). A study of selected maërl beds in Irish waters and their potential for sustainable extraction. *Marine Resource Series, No. 10.* Marine Institute, Dublin.
- Diario Oficial de Galicia. (2007). Catálogo galego de especies (Decreto 88/2007). D.O.G. 89: 7409-7423.
- Donnan, D.W. & Moore, P.G. (2003). International workshop on the conservation and management of maërl. *Aquatic Conservation, Marine and Freshwater Issues*, 13, 1–78.
- Donze M. (1968). The algal vegetation of the Ría de Arosa (NW. Spain). *Blumea* 16: 159-192.
- Farnham, W. F. & Bishop, G. M. (1985). Survey of the Fal Estuary, Cornwall. 18th Symposium of the Underwater Association for Scientific Research. pp 53-63.
- Foster, M. S. (2001). Rhodoliths: between rocks and soft places. *Journal of Phycology* 37: 659-667.
- Freiwald, A. & Henrich, R. (1994) Reefal coralline algal build-ups within the Arctic Circle: morphology and sedimentary dynamics under extreme environmental seasonality. *Sedimentology* 41: 963-984.
- Gautier, M. (1971). Le maërl sur le littoral de la Bretagne. *Cahiers Oceanographiques* 23: 171–191.
- Grall, J. & Glémarec, M. (1997a). Using biotic indices to estimate macrobenthic community perturbations in the Bay of Brest. *Estuarine, Coastal and Shelf Science*, 44 (suppl A), 43–53.
- Grall, J. & Glémarec, M. (1997b) Biodiversity of maërl beds in Brittany: Functional approach and anthropogenic impact. *Vie Milieu* 47(4): 339-349.
- Grall, J. & Hall-Spencer, J.M. (2003) Problems facing maërl conservation in Brittany. *Aquatic Conservation: Marine and Freshwater Ecosystems* 13: S55-S64.
- Grall, J. (2003). Les bancs de maërl (<http://www.rebent.org/>)

- Grall, J., Le Loc'h, F., Guyonnet, B., Riera, P. (2006) Community structure and food web based on stable isotopes ( $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$ ) analyses of a North Eastern Atlantic maërl bed. *Journal of Experimental Marine Biology and Ecology* 338: 1–15
- Gunnarsson, K. (1977) Þörungar á kóralsetlögum í Arnarfirði. Sérprentum úr Hafrannsóknir 10. hefti 1977, 10 pp.
- Hall-Spencer, J.M (1998) Conservation issues concerning the molluscan fauna of maërl beds. *Journal of Conchology Special Publication* 2: 271–286.
- Hall-Spencer, J.M. (2005). Ban on maërl extraction. *Marine Pollution Bulletin* 50: 121–124
- Hall-Spencer, J.M. & Bamber R (2007) Effects of salmon farming on benthic Crustacea. *Ciencias Marinas* 33: 353-366.
- Hall-Spencer, J.M. & Moore, P.G. (2000a). *Limaria hians* (Mollusca: Limacea): a neglected biogenic reef-forming keystone species. *Aquatic Conservation: Marine and Freshwater Ecosystems* 10: 267-277
- Hall-Spencer, J.M., & Moore, P.G. (2000b). Scallop dredging has profound, long-term impacts on maërl habitats. *ICES Journal of Marine Science* 57: 1407–1415.
- Hall-Spencer, J.M., Grall, J., Moore, P.G. & Atkinson, R.J.A. (2003). Bivalve fishing and maërl-bed conservation in France and the UK – retrospect and prospect. *Aquatic Conservation: Marine and Freshwater Ecosystems*. 13: S33-S41.
- Hall-Spencer J.M., Rodolfo-Metalpa R., Martin S., Ransome E., Fine M., Turner S.M., Rowley S.J., Tedesco D., Buia M-C. (2008) Volcanic carbon dioxide vents reveal ecosystem effects of ocean acidification. *Nature* 454: 96-99.
- Hall-Spencer, J.M., White, N., Gillespie, E., Gillham, K., Foggo, A. (2006). Impact of fish farms on maërl beds in strongly tidal areas. *Marine Ecology Progress Series* 326:1-9.
- Hamel G, Lemoine M. (1953). Corallinacées de France et d'Afrique du Nord. *Archives du Museum National D'Histoire Naturelle* 7: 15–136.
- Hardiman, P.A., Rolfe, M.S. & White, I.C., (1976). Lithothamnion studies off the south west coast of England. Report to the Fisheries Improvement Committee. International Council for the Exploration of the Sea (CM Papers and Reports), CM 1976/K:9, 13 pp.
- Hauton, C., Hall-Spencer, J.M. & Moore, P.G. (2003). Ecological impacts of hydraulic bivalve dredging on maërl. *ICES Journal of Marine Science* 60: 381–392.
- Hily, C. & Grall, J. (2003) Suivi stationnel des bancs de maërl. FT02-2003-01.doc. ([www.rebent.fr](http://www.rebent.fr))
- Hinojosa-Arango, G. & Riosmena-Rodriguez, R. (2004). Influence of rhodolith-forming species and growth-form on associated fauna of rhodolith beds in the central-west Gulf of California, Mexico. *P.S.Z.N.: Marine Ecology* 25: 109-127.
- Hiscock, K. and Kimmance, S. (2003) Review of current and historical time-series seabed biological studies in the UK and near Europe. Report from the Marine Biological Association to the Joint Nature Conservation Committee. (JNCC Contract: F90-01-563)
- Husa, V., K. Sjötn and Lein, T.E. (2004). The newly introduced species *Heterosiphonia japonica* Yendo (Dasyaceae, Rhodophyta): geographical distribution and abundance at the Norwegian southwest coast. *Sarsia* 89: 211-217.

ICES (2002) Review of the draft OSPAR List of Threatened and Declining Species and Habitats. Report of the ICES Advisory Committee on Ecosystems. Section 6 and Annex 1

IMPACT (Oslo and Paris Conventions for the Prevention of Marine Pollution Working Group on Impacts on the Marine Environment). (1998). Marine habitat reviews presented by the United Kingdom. English Nature, Peterborough.

Irvine, L.M. & Chamberlain, Y.M.C. (1994). Seaweeds of the British Isles, Volume 1, Part 2B. British Museum (Natural History), London

Jones, L.A., Hiscock, K., & Connor, D.W. (2000). Marine habitat reviews. A summary of ecological requirements and sensitivity characteristics for the conservation and management of marine SACs. Joint Nature Conservation Committee, Peterborough. (UK Marine SACs Project report).

Kamenos, N.A., Moore, P.G. & Hall-Spencer, J.M. (2004a) Small-scale distribution of juvenile gadoids in shallow inshore waters; what role does maërl play? ICES Journal of Marine Science 61: 422–429

Kamenos, N.A., Moore, P.G., & Hall-Spencer, J.M. (2004b). Attachment of the juvenile queen scallop (*Aequipecten opercularis* (L.)) to maërl in mesocosm conditions; juvenile habitat selection. *Journal of Experimental Marine Biology and Ecology*, 306: 139–155.

Kamenos, N.A., Moore, P.G., & Hall-Spencer, J.M. (2004c). The importance of maërl grounds for recruitment of queen scallops (*Aequipecten opercularis*) and other invertebrates. *Marine Ecology Progress Series*, 274: 183–189.

Keegan, B.F. (1974). The macrofauna of maërl substrates on the west coast of Ireland. *Cahiers de Biologie Marine* 15: 513–530.

King, R.J. & Schramm, W. (1982). Calcification in the maërl coralline alga *Phymatolithon calcareum*: effects of salinity and temperature. *Marine Biology* 70: 197–204.

Lemoine P. (1910). Répartition et mode de vie du maërl (*Lithothamnium calcareum*) aux environs de Concarneau (Finistère). *Annales de l'Institut Océanographique*, Paris 1: 1–29.

Maggs, C.A. & Guiry, M.D. (1982). Morphology, phenology and photoperiodism in *Halymenia latifolia* Kütz. (Rhodophyta) from Ireland. *Botanica Marina* 25: 589–599.

Maggs, C.A. & Guiry, M.D. (1987). *Gelidiella calcicola* sp. nov. (Rhodophyta) from the British Isles and Northern France. *British Phycological Journal* 22: 417–434.

Maggs, C.A. & Guiry, M.D. (1989). A re-evaluation of the crustose red algal genus *Cruoria* and the family *Cruoriaceae*. *British Phycological Journal* 24: 253–269.

Maggs, C.A. (1983). A phenological study of the epiflora of two maërl beds in Galway Bay. PhD Thesis, National University of Ireland, Galway, 346 pp.

Martin, S., Clavier, J., Chauvaud, L., & Thouzeau, G. (2007a) Community metabolism in temperate maërl beds. II Nutrient fluxes. *Marine Ecology Progress Series* 335: 31–41

Martin, S., Clavier, J., Chauvaud, L., & Thouzeau, G. (2007b) Community metabolism in temperate maërl beds. I Carbon and carbonate fluxes. *Marine Ecology Progress Series* 335: 31–41.

Martin, S., Clavier, J., Guarini, J-M., Chauvaud, L., Hily, C., Grall, J., Thouzeau, G., Jean, F. & Richard, J. (2005) Comparison of *Zostera marina* and maërl community metabolism. *Aquatic Botany* 83: 161–174.

- Martin S., Rodolfo-Metalpa R., Ransome E., Rowley S., Buia M-C., Gattuso J-P., Hall-Spencer J.M. (2008) Effects of naturally acidified seawater on seagrass calcareous epibionts. *Biology Letters*, in press.
- Mitchell A.J. & Collins, K.C. (2004). Understanding the distribution of maërl, a calcareous seaweed, off Dorset, UK, pp. 65-82. In: Nishida, T., Kailola, P.J., and Hollinworth, C.E. (Editors). 2004. GIS/Spatial Analyses in Fishery and Aquatic Sciences (Vol. 2). Fishery-Aquatic GIS Research Group, Saitama, Japan.
- Mora Bermúdez, J. (1980). Poblaciones bentónicas de la Ria de Arosa. PhD thesis, The University of Santiago de Compostela, Spain.
- Myers, A.A. & McGrath, D. (1980). A new species of *Stenothoe* Dana (Amphipoda, Gammaridea) from maërl deposits in Kilkerran Bay. *Journal of Life Sciences, Royal Dublin Society* 2: 15–18.
- Myers, A.A. & McGrath, D. (1983). The genus *Listriella* (Crustacea: Amphipoda) in British and Irish waters, with the description of a new species. *Journal of the Marine Biological Association of the United Kingdom* 63: 347–353.
- O'Connor, B.D.S. & Shin, P.K.S. (1983). *Hesiospina similis* (Hessle) (Polychaeta, Hesionidae) from Galway Bay, west coast of Ireland, with notes on its taxonomic status and distribution. *Cahiers de Biologie Marine* 24: 355–361.
- OSPAR (2006) Case Reports for the Initial List of Threatened and/or declining Species and Habitats in the OSPAR Maritime Area. OSPAR Commission, London.
- Paturel, G. (1898). Composition chimique des sables calcaires du finistère. Publication du Laboratoire Agricole Departemental, 31 pp.
- Peña, V. & Bárbara, I. (2004). Diferenciación morfológica y anatómica entre *Lithothamnion corallioides* y *Phymatolithon calcareum* en dos bancos de maërl de la Ría de Arousa (N.O. Península Ibérica). *Anales de Biología* 26: 21-27.
- Peña, V. & Barbera, I. (2007b) Los fondos de maërl en Galicia. *Boletín informativo de la sociedad española de ficología, ALGAS* 37: 11-18 (available from [www.sefalgas.org](http://www.sefalgas.org))
- Peña V, Bárbara I. (2007a). Maërl community in the northwestern Iberian Peninsula: a review of floristic studies and long-term changes. *Aquatic Conservation: Marine and Freshwater Ecosystems* 17: 1-28.
- Potin, P., Floc'h, J. Y., Augris, C. & Cabioch, J. (1990). Annual growth rate of the calcareous red algae *Lithothamnion corallioides* (Corallinales, Rhodophyta) in the Bay of Brest, France. *Hydrobiologia* 204: 263-267.
- Sanchez-Mata, A. & Mora, J. (2000). A review of marine aquaculture in Spain: production, regulations and environmental monitoring. *Journal of Applied Ichthyology* 16: 209-213.
- Scott, R. & Moore, P. G. (1996). The status and distribution of maërl in Scotland with regard to the EC Habitats Directive. A desk study prepared for Scottish Natural Heritage. University Marine Biological Station, Millport. 55 pp.
- Smith, A. D. & Roth, A. A. (1979) Effect of carbon dioxide concentration on calcification in the red coralline alga *Bossiella orbigniana*. *Marine Biology* 52: 217-225.
- Southward, E.C. (1957). The distribution of Polychaeta in offshore deposits in the Irish Sea. *Journal of the Marine Biological Association of the United Kingdom*. 36: 49–75.

- Steller, D.L. et al. (2003). Rhodolith bed diversity in the Gulf of California: the importance of rhodolith structure and consequences of disturbance. *Aquatic Conservation, Marine and Freshwater Ecosystems* 13: 5–20.
- UKBAP. (2000). UK Biodiversity Group Tranche 2 Action Plans. Volume V – maritime species and habitats. English Nature, Peterborough. 242 pp.
- Veale, L., Thompson, R. & Bates, M. (1999). Isle of Man sublittoral survey: 1994-1997. In: H. Davies (Editor), *Irish Sea Forum, Isle of Man*, pp. 35-49.
- Vilas, F., Bernabeu, A.M. & Mendez, G. (2005) Sediment distribution pattern in the Rías Baixas (NW Spain): maine facies and hydrodynamic dependence. *Journal of Marine Systems* 54: 261-276.
- Vize, S.J. (2005). The distribution and biodiversity of maërl beds in Northern Ireland. PhD thesis, Queen's University Belfast.
- Wilson, S., Blake, C., Berges, J.A. & Maggs, C.A. (2004) Environmental tolerances of free-living coralline algae (maërl): implications for European maërl conservation. *Biological Conservation* 120: 283–293.
- Wilson, S., Johnson, M.P., Kelly, J., Clarkin, P.E. & Maggs, C.A. (2007) Assessment of extent and abundance of maërl beds and their associated biodiversity along the East Antrim coast. Report to EHS, Northern Ireland.
- Woelkerling WJ (1988) *The red coralline algae: an analysis of the genera and subfamilies of nongeniculate Corallinaceae*. Oxford University Press, New York.

## Annex 4: Overview of Dinter biogeographic regions of the OSPAR area

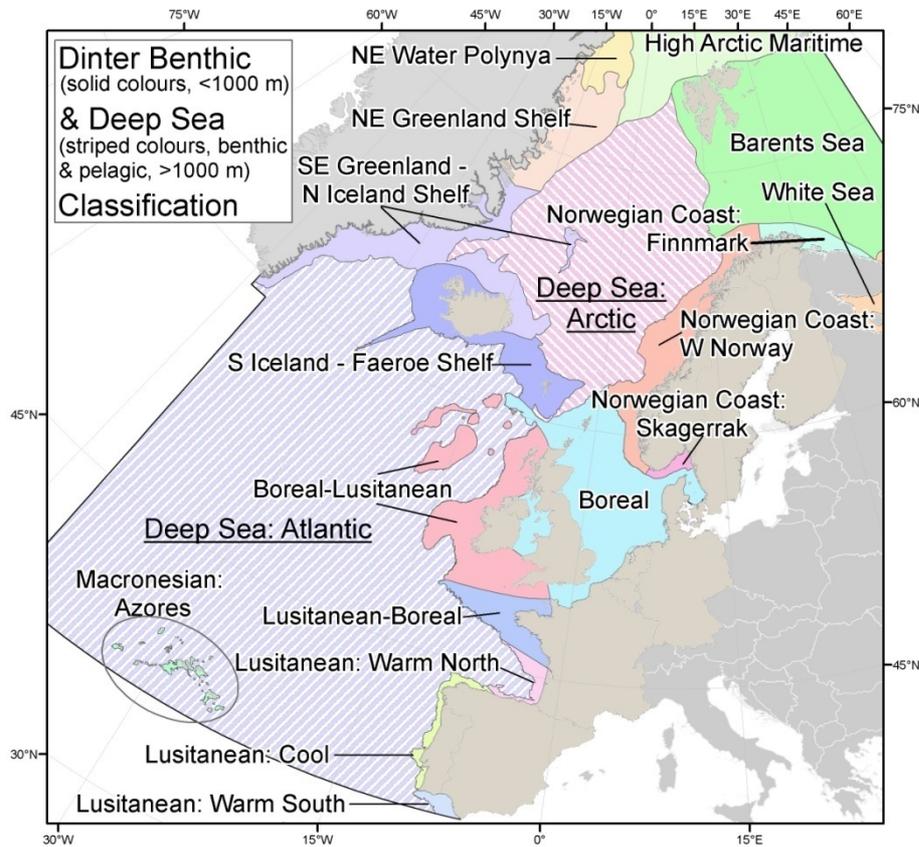


Figure 12. Benthic biogeographic regions (<1000 m depth) and Deep Sea biogeographic regions (>1000 m, which includes benthos and deep waters) proposed by Dinter (2001).



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