Lithothamnion glaciale maerl beds in tide-swept variable salinity infralittoral gravel

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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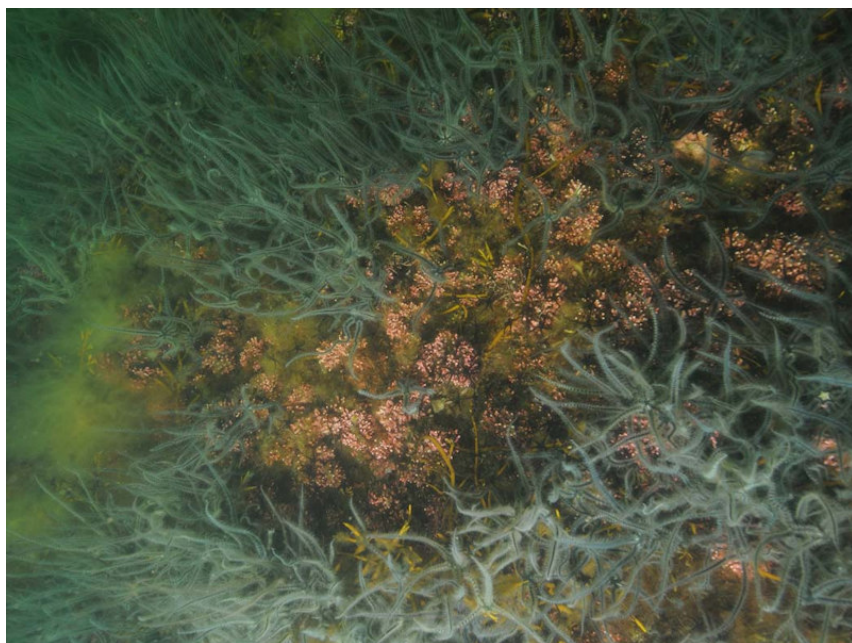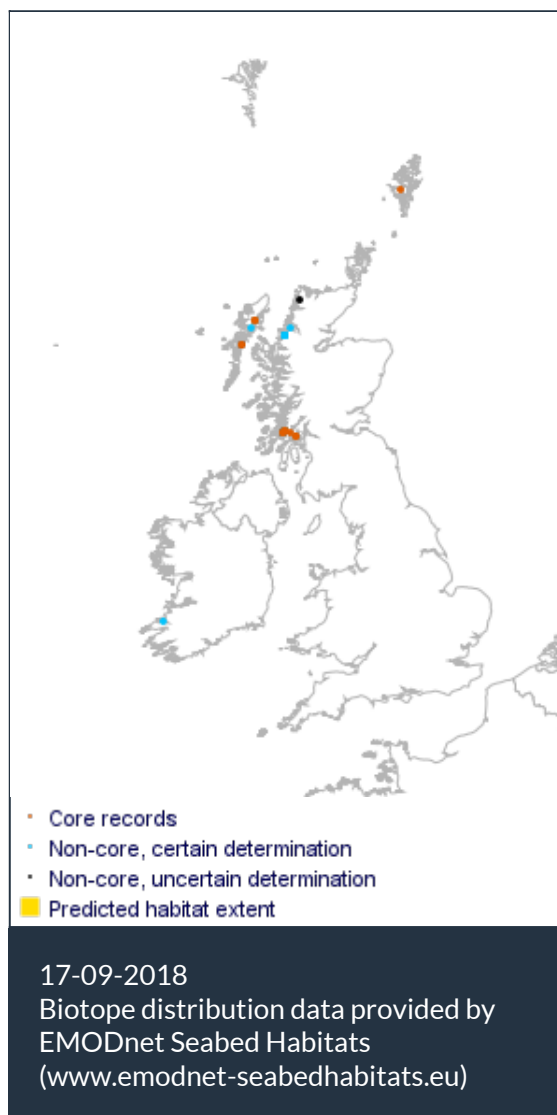
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Lithothamnion glaciale **maerl beds in tide-swept variable salinity infralittoral gravel**
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- Core records
- Non-core, certain determination
- Non-core, uncertain determination
- Predicted habitat extent

17-09-2018
Biotope distribution data provided by
EMODnet Seabed Habitats
(www.emodnet-seabedhabitats.eu)

Researched by   Frances Perry & Angus Jackson   **Refereed by**   Prof. Jason Hall-Spencer

Summary

☰ UK and Ireland classification

EUNIS 2008	A5.512	*Lithothamnion glaciale* maerl beds in tide-swept variable salinity infralittoral gravel
JNCC 2015	SS.SMp.Mrl.Lgla	*Lithothamnion glaciale* maerl beds in tide-swept variable salinity infralittoral gravel
JNCC 2004	SS.SMp.Mrl.Lgla	*Lithothamnion glaciale* maerl beds in tide-swept variable salinity infralittoral gravel
1997 Biotope	SS.IGS.Mrl.Lgla	*Lithothamnion glaciale* maerl beds in tide-swept variable salinity infralittoral gravel

🏷 Description

Upper infralittoral tide-swept channels of coarse sediment subject to variable or reduced salinity which support distinctive beds of *Lithothamnion glaciale* maerl 'rhodoliths'. *Phymatolithon calcareum*

may also be present as a more minor maerl component. This biotope can often be found at the upper end of Scottish sea lochs where the variable salinity of the habitat may not be immediately obvious. Associated fauna and flora may include species found in other types of maerl beds (and elsewhere), e.g. *Chaetopterus variopedatus*, *Lanice conchilega*, *Mya truncata*, *Plocamium cartilagineum* and *Phycodrys rubens*. SS.SMp.Mrl.Lgla, however, also has a fauna that reflects the slightly reduced salinity conditions, e.g. *Psammechinus miliaris* is often present in high numbers along with other grazers such as chitons and *Tectura* spp. *Hyas araneus*, *Ophiothrix fragilis* and *Henricia oculata* are also fairly typically present at sites. In Scottish lagoons this biotope may show considerable variation but the community falls within the broad description defined here. (Information from Connor *et al.*, 2004; JNCC, 2015).

↓ Depth range

0-5 m, 5-10 m

🏛 Additional information

In all maerl beds, the dominant maerl forming species creates a unique habitat that supports a diverse assemblage of species. But all maerl forming species are slow growing and loss of the maerl bed would result in loss of the biotope. Therefore, the sensitivity of maerl beds is dependent on the sensitivity of the maerl species themselves. *Lithothamnion glaciale* dominates this biotope SMP.Mrl.Lgla. A newly described species of maerl, *Lithothamnion erinaceum,* is found in Northern Ireland, Scotland, Iceland and Norway together with *Lithothamnion glaciale* (Melbourne *et al.*, 2017) but has not yet been assigned to a biotope.

✔ Listed By

- none -

🔗 Further information sources

Search on:

G 𝓰 G JNCC

Habitat review

♻ Ecology

Ecological and functional relationships

The ecological relationships of maerl beds can be very complex. The maerl thalli provide considerable surface area to which both flora and fauna can attach. The maerl nodules themselves may be directly grazed by species like *Tectura virginea*. The surface film of microalgae and detritus can also be grazed by animals such as *Psammechinus miliaris*. The loose structure permits water circulation and oxygenation to considerable depth. As a consequence of this loose structure, maerl provides shelter for a wide of fauna e.g. molluscs (Hall-Spencer, 1998) and amphipods (Grave de, 1999). The loose structure also permits animals to burrow to considerable depths (at least 60 cm) within the gravel.

Seasonal and longer term change

Seasonal changes in the biotope potentially include variations in the amount of ephemeral algae growing on and over the maerl. Temperature controls the development of reproductive conceptacles in *Lithothamnion glaciale* (Adey, 1970).

Habitat structure and complexity

Habitat complexity is bought about by the branching nature of the maerl and the open spaces between nodules that occur. However, the maerl nodules are frequently loose and mobile preventing colonization by many species. In some instances, the branched nodules can also interlock creating a more stable environment. Species such as *Saccharina latissima* and *Lanice conchilega* may also help to bind the maerl together. The highly branching nature of the maerl thalli permits oxygenation and circulation of water deep within the sediment. This is exploited by many burrowing animals and deep burrowing (to 68 cm) fauna are a notable feature of maerl beds (Hall-Spencer & Atkinson, 1999). Most surveys under-record the species in the biotope, primarily because the vast majority of species live below the maerl surface. Maerl in general is known as a particularly diverse habitat with over 150 macro-algal species and 500 benthic faunal species recorded (Birkett *et al*., 1998(a)).

Productivity

Maerl beds may contain dead as well as live nodules. Productivity will depend on the relative proportions of dead and live nodules. In the British Isles this biotope tends to occur in shallow waters down to 10 metres in depth where algal primary productivity may be boosted by the occurrence of epiphytic algae. Some maerl beds may have very high faunal densities and in these, secondary production may be very high.

Recruitment processes

The main recruitment mechanism of *Lithothamnion glaciale* is uncertain. Individual plants have reproductive conceptacles (whether sexual or asexual is unclear) during the winter months and are sterile in summer (Hall-Spencer, 1994 cited in Birkett *et al*., 1998). Recruitment may occur via planktonic dispersal of sexual or asexual propagules. Vegetative growth and division of maerl nodules also forms a propagation mechanism in the biotope. In fact, in the British Isles this may be

the only form of propagation in the species *Phymatolithon calcareum* (also a minor component of this biotope) and *Lithothamnion corallioides*. Hall-Spencer (pers. comm.) has observed that colonization of new locations by maerl can be mediated by a 'rafting' process where maerl thalli are bound up with other sessile organisms that are displaced and carried by currents (e.g. *Saccharina latissima* (studied as *Laminaria saccharina*) holdfasts after storms). Of the other species typically found in this biotope , *Psammechinus miliaris* is highly fecund with relatively long lived planktonic larva that may disperse and colonize from long distances. *Ophiothrix fragilis* also has a long-lived planktonic larva that can disperse over distance.

Time for community to reach maturity

Lithothamnium glaciale is very slow growing (although faster than other maerl species (Irvine & Chamberlain, 1994). Individual plants are estimated to live from between 10-50 years (Adey, 1970) and would need a long period for populations to expand into a 'bed'. Development into a thick bed with the associated interstices and open structure important for the development of the associated community would take even longer. Maerl beds are known to be extremely long lived with lifespan of the habitat being 6000 years or more (Birkett *et al.*, 1998(a)). Within the biotope, the community is dependent on the growth of a surface veneer of photosynthetically active maerl thalli.

Additional information

Outward appearances of the biotope may be misleading with respect to dominant trophic groups. Grall & Glémarec (1997) found that dominant trophic groups in maerl beds varied according to the assessment criteria used. In terms of species richness, carnivores were most dominant, while detritivores were the most abundant and surface deposit feeders had the highest biomass.

🖼 Preferences & Distribution

Habitat preferences

Depth Range	0-5 m, 5-10 m
Water clarity preferences	No information found
Limiting Nutrients	Calcium
Salinity preferences	Full (30-40 psu), Variable (18-40 psu)
Physiographic preferences	Enclosed coast / Embayment, Strait / sound
Biological zone preferences	Infralittoral
Substratum/habitat preferences	Coarse sediments, Gravel / shingle, Maerl
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Strong 3 to 6 knots (1.5-3 m/sec.), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Sheltered, Very sheltered
Other preferences	

Additional Information

Growth of *Lithothamnion glaciale* is maximal at 10-12°C (Adey, 1970). Growth of *Lithothamnion glaciale* is impaired at reduced salinities (Adey, 1970). Distribution of maerl is dependent on several factors. Living maerl has poor tolerance of desiccation and so is typically found subtidally (Hall-

Spencer, 1998). As a photosynthetic organism there is a requirement for light which restricts the species to depths shallower than 32 m in the relatively turbid waters of northern Europe (Hall-Spencer, 1998). Some shelter from wave action is required to prevent physical damage, dispersal or burial although some degree of water movement is important to ensure that silt does not smother the maerl bed. King & Schramm (1982) report that ionic calcium concentration is the main factor affecting growth of maerl in culture experiments rather than salinity *per se* (although this has not been shown in the field). Uptake of calcium carbonate occurs optimally at 30 psu.

🐾 Species composition

Species found especially in this biotope

- *Cruoria cruoriiformis*
- *Gelidiella calcicola*
- *Halymenia latifolia*
- *Scinaia turgida*
- *Tectura virginea*

Rare or scarce species associated with this biotope

-

Additional information

- Maerl biotopes are recognised as having particularly rich and diverse communities.
- The BIOMAERL team (1999) recorded a maximum species richness of 490 from a maerl bed at one Scottish site. From maerl biotopes in general, over 150 macroalgal species and 500 benthic faunal species have been recorded (Birkett *et al.*, 1998(a)).
- Species richness can vary considerably in maerl beds, even within the same geographical area. There are also potential seasonal changes in species richness although this applies particularly to epiphytic algae.
- Maerl beds that are or have been dredged for scallops have modified species compositions, reduced species richness and abundance (Hall-Spencer & Moore, 2000a).
- There are several species of algae that are apparently restricted to calcareous habitats and may be characteristically found in maerl beds (e.g. *Halymenia latifolia*, *Scinaia turgida*, *Gelidiella calcicola*, *Gelidium maggsiae* & *Cruoria cruoriiformis*) (Birkett *et al.*, 1998a). These species are found in maerl beds in general, whether or not they are found in conditions of reduced salinity is uncertain.*Tectura virginea* can be considered to be associated with maerl although it is most common on encrusting coralline algal species. There are several species of mollusc that are common in maerl beds (e.g. *Steromphala cineraria*, *Rissoa interrupta*, *Modiolarca tumida*, *Hinia incrassata*, *Tricolia pullus* and *Hiatella arctica*) but these are also common in other habitats and probably either reflect the nature of the substratum or are widespread in lower shore and sublittoral environments.
- Neither the MNCR surveys (JNCC, 1999) nor Birkett *et al.*(1998a) specifically record any species recorded from maerl beds as being rare or scarce. However, this is likely to be caused by under-recording or difficulties of identification of rare or scarce species.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Maerls beds are formed by calcareous red algae that grow as unattached nodules (occasionally crusts) forming dense but relatively open beds of coralline algal gravel. Beds of maerl form on a variety of sediments and occur on the open coast and in tide-swept channels of marine inlets (the latter are often stony). In fully marine conditions, the dominant maerl is typically *Phymatolithon calcareum* or *Lithothamnion coralloides* in England. Maerl beds support diverse communities of burrowing infauna, especially bivalves, and interstitial invertebrates; including suspension feeding polychaetes and echinoderms.

Long-lived maerl thalli and their dead remains build upon underlying sediments to produce deposits with a three-dimensional structure that is intermediate in character between hard and soft grounds (Jacquotte, 1962; Cabioch, 1969; Keegan, 1974; Hall-Spencer, 1998; Barbera *et al*., 2003). Thicker maerl beds occur in areas of water movement (wave or current based) while sheltered beds tend to be thinner with more epiphytes. The associated community varies with underlying and surrounding sediment type, water movement, depth of bed and salinity (Tyler-Walters, 2013).

Maerl beds are highly variable and range from a thin layer of living maerl on top of a thick deposit of dead maerl to a layer of live maerl on silty or variable substrata to a deposit of completely dead maerl or maerl debris of variable thickness. Live maerl beds vary in the depth and proportion of 'live maerl' present (Birkett *et al*., 1998a). In areas subject to wave action, they may form wave ripples or mega ripples e.g. in Galway Bay (Keegan, 1974) and in Stravanan Bay (Hall-Spencer & Atkinson, 1999). Maerl beds also show considerable variation in water depth, the depth of the bed, and biodiversity (see Birkett *et al*., 1998a). They also vary in the dominant maerl forming species, with *Phymatolithon calcareum* dominating northern beds while both *Phymatolithon calcareum* and *Lithothamnion coralloides* occur in the south west of England and Ireland. *Lithothamnion glaciale* and *Lithothamnion erinaceum* also occur in northern waters and replaces *Lithothamnion coralloides* in Scotland (Birkett *et al*., 1998a; Melbourne *et al*., 2017). Birkett *et al*. (1998a) list other minor maerl forming species in the UK, however, their taxonomic status remains unresolved (Pena *et al*., 2013).

Maerl has a complex three dimensional structure with interlocking thalli providing a wide range of niches for infaunal and epifaunal invertebrates (Birkett *et al*., 1998a). Un-impacted maerl grounds are more structurally complex than those which have been affected by dredging (Kamenos *et al*., 2003). The interstitial space provided by maerl beds allow water to flow through the bed, and oxygenated water to penetrate at depth so that other species can colonize the bed to greater depths than most other sediments. Maerl forming species are the pivotal, ecosystem engineer and biogenic reef species in maerl beds (including this biotope and its sub-biotopes). The integrity and survival of maerl beds are dependent on the thin surface layer of living maerl (Birkett *et al*., 1998a; Hall-Spencer & Moore, 2000a&b). Therefore, maerl species are the single most important functional group with respect to the sensitivity of this habitat. The other members of the community occur in other coarse substrata, although the maerl habitat supports a diverse community. Where appropriate, the sensitivity of other members of the community is mentioned. The biotopes assessed under this review are live maerl beds. The sensitivity of 'dead' maerl beds was reviewed by Tyler-Walters (2013).

Resilience and recovery rates of habitat

Maerl beds occur from the tropics to the poles (Foster, 2001; Hinojosa-Arango & Riosmena-Rodriquez, 2004). Both dead and live maerl contribute to subtidal biotopes. Maerl thalli grow very slowly (Adey & McKibbin, 1970; Potin *et al.*, 1990; Littler *et al.*, 1991; Hall-Spencer, 1994; Birkett *et al.*, 1998a Hall-Spencer & Moore, 2000a,b) so that maerl deposits may take hundreds of years to develop, especially in high latitudes (BIOMAERL, 1998). Species of maerl are extremely slow growing. Growth rates of European maerl species range between tenths of a millimetre to 1 millimetre per annum (Bosence & Wilson, 2003). The growth rates of the three most abundant species of maerl in Europe (*Phymatolithon calcareum*, *Lithothamnion glaciale* and *Lithothamnion coralloides*) ranged between 0.5 to 1.5 mm per tip per year under a wide range of field and laboratory conditions (Blake & Maggs, 2003).

Individual maerl thalli may live for >100 years (Foster, 2001). Maerl beds off Brittany are over 5500 years old (Grall & Hall-Spencer, 2003) and the maerl bed at St Mawes Bank, Falmouth was estimated to have a maximum age of 4000 years (Bosence & Wilson, 2003) while carbon dating suggested that some established beds may be 4000 to 6000 years old (Birkett et al. (1998a). A maerl bed in the Sound of Iona is up to 4000 years old (Hall-Spencer *et al.*, 2003). Maerl is highly sensitive to damage from any source due to this very slow rate of growth (Hall-Spencer, 1998). Maerl is also very slow to recruit as it rarely produces reproductive spores. Maerl is considered to be a non-renewable resource due to its very slow growth rate and its inability to sustain direct exploitation (Barbera *et al.*, 2003; Wilson *et al.*, 2004).

Maerl species in the UK propagate mainly by fragmentation (Wilson *et al.*, 2004). Recruitment of *Phymatolithon calcareum* is mainly through vegetative propagation. Although spore bearing individuals of *Phymatolithon calcareum* thalli have been found in the British Isles, the crustose individuals that would result from sexual reproduction have yet to be recorded in the British Isles (Irvine & Chmberlain, 1994). Recruitment may occur from distant populations that exhibit sexual reproduction and have crustose individuals (e.g. Brittany). Hall-Spencer (pers. comm.) observed that colonization of new locations by maerl can be mediated by a 'rafting' process where maerl thalli are bound up with other sessile organisms that are displaced and carried by currents (e.g. *Saccharina latissima* holdfasts after storms). Cabioch (1969) suggested that *Phymatolithon calcareum* may have phasic reproduction with peaks every six years. This may account for observed changes in the relative proportions of live *Lithothamnion coralloides* and *Phymatolithon calcareum* in maerl beds. Dominance cycles with periods of about thirty years have been recorded on some of the maerl beds of northern Brittany. Adey & McKibbin (1970) undertook growth studies of *Phymatolithon calcareum* in the field and under laboratory conditions. Field studies in the Ria de Vigo, show that growth occurs predominantly in the summer and suggests an annual growth of about 0.55 mm/year for branch tips of *Phymatolithon calcareum* (Adey & McKibbin, 1970). Newly settled maerl thalli have never been found in the British Isles (Irvine and Chamberlain, 1994). Hall-Spencer (2009) wrote a maerl recovery report for the Port of Falmouth development initiative. Hall-spencer (2009) suggested that a live maerl bed would take 1000's of years to return to the site of navigation channel after planned capital dredging in the Fal estuary. He also suggested that it would take 100's of years for live maerl to grow on a translocated bed, based on the growth and accumulation rates of maerl given by Blake *et al.* (2007) (Hall-Spencer, 2009).

The BIOMAERL project confirmed the high levels of biodiversity associated with maerl beds that had been recorded from numerous other projects (Barbera *et al.*, 2003; BIOMAERL, 1998, 1999). The maerl thalli are frequently loose and mobile preventing colonization by many species. However, deep burrowing fauna (to 68 cm) are a notable feature of this biotope (Hall-Spencer & Atkinson, 1999). Maerl is known as a particularly diverse habitat with over 150 macroalgal species and 500 benthic faunal species recorded (Birkett *et al.*, 1998a). To date, 349 macroalgal species

have been recorded on maerl beds in the North East Atlantic (Peña *et al.*, 2014). Around the UK there are several maerl specialists, e.g. *Cruoria cruoriiformis*, *Cladophora rhodolithocola* and *Gelidiella calcicola* (Peña *et al.*, 2014). The sea cucumber *Neopentadactyla mixta* can reach densities of up to 400 per square metre in loose gravels such as maerl (Smith & Keegan, 1985).

In an analysis of re-colonization processes following cessation of maerl dredging in Ireland, De Grave & Whitaker (1999a) found clear differences in the benthos between dredged and fallow sites but they were unable to determine whether there had been a return to pre-dredging conditions as there were no pre-dredge data (Hall-Spencer, 2009). The diverse nature of communities within maerl beds results in a high level of ecological function. Hall-Spencer (2009) stated that within a translocated maerl bed, from which the long-lived species such as *Dosinia exoleta* and *Mya truncata* had been killed, could take 20 – 50 years to recover, assuming dead or live maerl remained. De Grave & Whitaker (1999) compared a dredged (extracted) maerl bed with one that been left 'fallow' for six months in Bantry Bay, Ireland. They noted that the dredged bed had significantly fewer molluscs than the fallow bed, but significantly more crustaceans and oligochaetes. Hall-Spencer & Moore (2000a,b) examined the recovery of maerl community after scallop dredging in previously un-dredged and dredged sites in Scotland. In comparison with control plots, mobile epibenthos returned within one month; fleshy macroalgae within six months; the abundance of *Cerianthus lloydii* was not significantly different after 14 months; other epifauna (e.g. *Lanice conchilega* and *Ascidiella aspersa*) returned after 1-2 years; but some of the larger sessile surface species (e.g. sponges, *Metridium senile*, *Modiolus modiolus* and *Limaria hians*) exhibited lower abundances on dredged plots after four years. Deep burrowing species (mud shrimp, large bivalves e.g. *Mya truncata* and the gravel sea cucumber *Neopentadactyla mixta*) were not impacted and their abundance changed little over the four year period. Hall-Spencer *et al.* (2003) noted that long-lived (>10 years) species (e.g. *Dosinia exoleta*) can occur at high abundances in maerl beds but that the sustainability of stocks is unknown at present. Hall-Spencer (2000a) noted that there was no significant difference between controls and experimentally dredged sites after 1-2 years at the sites previously subject to dredging. A review of historical data and the current situation at a maerl bed on the west coast of Scotland (Firth of Clyde) revealed extensive damage over the last 100 years (Hall-Spencer *et al.*, 2010). A living maerl bed with abundant large thalli and nests of the gaping file shell *Limaria hians* had become a bed of predominately dead maerl with few, small, live maerl thalli and no *Limaria hians* (Hall-Spencer & Moore, 2003).

Resilience assessment. The current evidence regarding the recovery of maerl suggests that if maerl is removed, fragmented or killed then it has almost no ability to recover. Therefore, resilience is assessed as **'Very low'** and probably far exceeds the minimum of 25 years for this category on the scale in cases where the resistance is Medium, Low or None. If the maerl is killed but dead maerl remains then the resident community may recover within 2-10 years (Tyler-Walters, 2013), but where the maerl is fragmented, species richness will probably decrease. However, Hall-spencer (2009) suggested that large long-lived species such as *Dosinia exoleta* and *Mya truncata* may take 20-50 years to recover.

Note. The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and

the habitat is structurally and functionally recognisable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

⚓ Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	Medium Q: Low A: NR C: NR	Very Low Q: High A: Medium C: High	Medium Q: Low A: Low C: Low

Maerl beds occur from the tropics to polar waters (Foster, 2001; Hinojosa-Arango & Riosmena-Rodriquez, 2004). Maerl beds in the North East Atlantic range from Norway to the African coast, although the component maerl species vary in temperature tolerance (Birkett *et al.*, 1998a; Wilson *et al.*, 2004). There are four species of biotope creating maerl beds in the UK. These species vary in their distribution within the UK, a phenomenon which is thought to be due to their temperature tolerances. Similarly, the associated communities within the maerl habitat differ and represent a diverse sample of species within the local area. *Lithothamnion coralloides* is absent from Scottish waters. This is due, either to winter temperatures dropping below the minimum survival temperature (between 2 and 5°C) or because the temperatures don't allow a suitable growing season (Adey & McKibbin, 1970; cited in Wilson *et al.*, 2004). *Lithothamnion corallioides* had a higher minimum survival temperature; dying at 2°C and surviving without growth at 5°C (Adey & McKibbin, 1970). In laboratory conditions, *Phymatolithon calcareum* survived down to 2°C, died at 0.4°C, and had a recorded optimum temperature for growth of 12-13°C (Adey & McKibbin 1970 cited in Wilson *et al.*, 2004). *Phymatolithon calcareum* showed no significant difference on photosynthetic activity at 9°C (the control), 17°C or 25°C for 4-5 weeks but were judged to be dead after 90 minutes at 40°C (Wilson *et al.*, 2004). Temperature appears to confine *Lithothamnion glaciale* to northern parts of the British Isles, possibly because reproductive conceptacles are only produced in winter when temperature fall below 9°C (Hall-Spencer, 1994 cited in Wilson *et al.*, 2004). In addition, Adey (1970) found optimal growth rates of *Lithothamnion glaciale* between 10-12°C and that development of reproductive conceptacles in *Lithothamnion glaciale* requires winter temperatures of between 1-5°C (Adey, 1970). Blake & Maggs (2003) reported that the growth rate of *Phymatolithon calcareum* in the laboratory was only slightly affected by temperature treatments (10, 14 and 18°C), with an optimum at 10°C while the growth rate of *Lithothamnion corallioides* was significantly affected by temperature with an optimum at 14°C, at which temperature it grew faster than *Phymatolithon calcareum*. Martin *et al.* (2006) reported that primary productivity in *Lithothamnion corallioides* was twice as high in August as in January to February in the Bay of Brest. They found that primary productivity, calcification and respiration rates *of Lithothamnion corallioides* increased as temperature rose from 10 to 16°C (Martin *et al.*, 2006).

The main maerl forming species have wide geographic ranges and their range indicates the limits of their temperature tolerance. *Phymatolithon calcareum* is a cold temperate species that ranges from Norway to the Mediterranean (Wilson *et al.*, 2004; Martin *et al.*, 2006) and tolerates high temperatures better than many subtidal temperate red algae (Wilson *et al.*, 2004). *Lithothamnion corallioides* is a warm temperate species ranging from Ireland and the south of Britain to the Mediterranean, while *Lithothamnion glaciale* and *Lithothamnion erinaceum* are cold temperate species that replace *Lithothamnion corallioides* in northern waters of the UK and the North East Atlantic (Melbourne *et al.*, 2017). Martin & Hall-Spencer (2017) noted that a 3°C increase in temperature above that normally experienced by tropical or warm-temperate coralline algae caused bleaching and adversely affected heath, rates of calcification and photosynthesis and

survival. Current trends in climate change driven temperature increases have already caused shifts in seaweed biogeography, as the tropical regions widen polewards, to the detriment of the warm-temperate region, and the cold-temperate region shrinks (Martin & Hall-spencer, 2017).

Sensitivity assessment. An increase in temperature at the benchmark level is unlikely to affect *Phymatolithon calcareum* present in this biotope (Wilson *et al.*, 2004). However, an increase in temperature may be detrimental to *Lithothamnion glaciale* and *Lithothamnion erinaceum* especially at the southernmost extent of their range. An increase in temperature of 2°C for a year is likely to reduce growth and reproduction in these species. Long-term climate-induced change in temperatures may result in loss of the extent of SS.SMp.Mrl.Lgla. Further research is required to determine the effect of a 2-5°C change in temperature on *Lithothamnion glaciale*. The northern species of maerl (*Lithothamnion glaciale* and *Lithothamnion erinaceum*) are likely to be vulnerable to sea surface warming in Scotland (Hall-Spencer, pers comm.). Therefore, a resistance of **'Medium'** is suggested at the benchmark level but with 'Low' confidence. Resilience is, therefore, **'Very low'**, and a sensitivity assessment of **'Medium'** is recorded.

Temperature decrease (local)	High	High	Not sensitive
	Q: High A: Medium C: Medium	Q: High A: High C: High	Q: High A: Medium C: Medium

Maerl beds occur from the tropics to polar waters (Foster, 2001; Hinojosa-Arango & Riosmena-Rodriquez, 2004). Maerl beds in the North East Atlantic range from Norway to the African coast, although the component maerl species vary in temperature tolerance (Birkett *et al.*, 1998a; Wilson *et al.*, 2004). There are four species of biotope creating maerl beds in the UK. These species vary in their distribution within the UK, a phenomenon which is thought to be due to their temperature tolerances. Similarly, the associated communities within the maerl habitat differ and represent a diverse sample of species within the local area. *Lithothamnion coralloides* is absent from Scottish waters. This is due, either to winter temperatures dropping below the minimum survival temperature (between 2 and 5°C) or because the temperatures don't allow a suitable growing season (Adey & McKibbin, 1970; cited in Wilson *et al.*, 2004). *Lithothamnion corallioides* had a higher minimum survival temperature; dying at 2°C and surviving without growth at 5°C (Adey & McKibbin, 1970). In laboratory conditions, *Phymatolithon calcareum* survived down to 2°C, died at 0.4°C, and had a recorded optimum temperature for growth of 12-13°C (Adey & McKibbin 1970 cited in Wilson *et al.*, 2004). *Phymatolithon calcareum* showed no significant difference on photosynthetic activity at 9°C (the control), 17°C or 25°C for 4-5 weeks but were judged to be dead after 90 minutes at 40°C (Wilson *et al.*, 2004). Temperature appears to confine *Lithothamnion glaciale* to northern parts of the British Isles, possibly because reproductive conceptacles are only produced in winter when temperature fall below 9°C (Hall-Spencer, 1994 cited in Wilson *et al.*, 2004). In addition, Adey (1970) found optimal growth rates of *Lithothamnion glaciale* between 10-12°C and that development of reproductive conceptacles in *Lithothamnion glaciale* requires winter temperatures of between 1-5°C (Adey, 1970). Blake & Maggs (2003) reported that the growth rate of *Phymatolithon calcareum* in the laboratory was only slightly affected by temperature treatments (10, 14 and 18°C), with an optimum at 10°C while the growth rate of *Lithothamnion corallioides* was significantly affected by temperature with an optimum at 14°C, at which temperature it grew faster than *Phymatolithon calcareum*. Martin *et al.* (2006) reported that primary productivity in *Lithothamnion corallioides* was twice as high in August as in January to February in the Bay of Brest. They found that primary productivity, calcification and respiration rates *of Lithothamnion corallioides* increased as temperature rose from 10 to 16°C (Martin *et al.*, 2006).

The main maerl forming species have wide geographic ranges and their range indicates the limits of their temperature tolerance. *Phymatolithon calcareum* is a cold temperate species that ranges from Norway to the Mediterranean (Wilson *et al.*, 2004; Martin *et al.*, 2006) and tolerates high temperatures better than many subtidal temperate red algae (Wilson *et al.*, 2004). *Lithothamnion corallioides* is a warm temperate species ranging from Ireland and the south of Britain to the Mediterranean, while *Lithothamnion glaciale* and *Lithothamnion erinaceum* are cold temperate species that replace *Lithothamnion corallioides* in northern waters of the UK and the North East Atlantic (Melbourne *et al.*, 2017).

Sensitivity assessment. A decrease in temperature at the benchmark level is unlikely to affect *Phymatolithon calcareum* (Wilson *et al.*, 2004) when present in this biotope. *Lithothamnion glaciale* has a more northern distribution in the UK and may benefit from a localised temperature decrease in the long-term, so that the relative abundance of *Lithothamnion glaciale* and *Phymatolithon calcareum* may change in the long-term. However, given the slow growth rates exhibited by maerls, no effect is likely to be perceived within the duration of the benchmark, but long-term climate change effects may be noticed in future. Therefore, SS.SMp.Mrl.Lgla probably has a '**High**' resistance to a decrease in temperature at the benchmark level. Resilience is, therefore '**High**', and sensitivity is assessed as '**Not sensitive**' at the benchmark level.

Salinity increase (local)	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

The majority of maerl beds occur in full salinity. Joubin, (1910 cited in Wilson *et al.*, 2004) thought that maerl beds were only present in areas with lowered salinity. Bosence (1976) found that, although surface salinities could be low, the benthic water was mostly fully saline. The only maerl species currently thought to create beds in biotopes with salinities below fully marine is *Lithothamnion glaciale* (Connor *et al.*, 2004), although the recently described *Lithothamnion erinaceum* might also. Wilson *et al.* (2004) noted that *Phymatolithon calcareum* and *Lithothamnion corallioides* were tolerant up to 40 psu while most subtidal seaweeds can survive up to 50 psu. The growth of *Phymatolithon calcareum* is impaired at salinities <24% (Adey & McKibbin, 1970; King & Schramm, 1982).

Sensitivity assessment. An increase in salinity above full is unlikely, except via the discharge of hypersaline effluents from desalination plants, none of which occur in the UK at present. Where the biotope was found in areas of reduced or variable salinity, an increase in salinity may result in an increase in biodiversity and a shift in the community to one more representative of full salinity. Maerl does not naturally occur within hypersaline areas, and although it may be able to tolerate a short-term increase in salinity, an increase to hypersaline conditions for a year would probably cause significant negative impacts. However, no evidence was found on which to base an assessment.

Salinity decrease (local)	Low	Very Low	High
	Q: Medium A: Medium C: Medium	Q: High A: Medium C: High	Q: Medium A: Medium C: Medium

The majority of maerl beds occur in full salinity. Although Joubin, (1910, cited in Wilson *et al.*, 2004) thought that maerl beds were only present in areas with lowered salinity, Bosence (1976) found that although surface salinities could be low, the benthic water was mostly fully saline. The only maerl species currently thought to survive in biotopes with salinities below fully marine is *Lithothamnion glaciale* (Connor *et al.*, 2004). The growth of *Phymatolithon calcareum* is impaired at

salinities <24 ppt (Adey & McKibbin, 1970; King & Schramm, 1982). However, Wilson *et al.* (2004) noted that *Phymatolithon calcareum* was more tolerant of low salinity than *Lithothamnion glaciale* in their experiments. Both species survived at 3 psu for five weeks but showed significantly reduced photosynthetic activity. However, at 15 psu, *Phymatolithon calcareum* recovered from the initial drop in photosynthetic activity, while *Lithothamnion glaciale* did not.

Sensitivity assessment. Where present, reduced salinity for an extended period of time would stress *Phymatolithon calcareum* and could lead to mortality. SS.SMp.Mrl.Lgla is characterized by *Lithothamnion glaciale* and can be found in both fully marine and variable salinity regimes. A decrease in salinity could result in a 'reduced' salinity regime. Experiments show that *Lithothamnion glaciale* does not recover from a relatively short-term exposure to 15 psu. This suggests that at the level of the benchmark prolonged exposure (for one year) to this pressure could cause significant mortality. Resistance has been assessed as **'Low'** and, as resilience is probably **'Very low'**, sensitivity is assessed as **'High'**. There is no information on the responses of other maerl species to a reduction in salinity.

Water flow (tidal current) changes (local)	Low	Very Low	High
	Q: Low A: NR C: NR	Q: High A: Medium C: High	Q: Low A: Low C: Low

Maerl requires enough water movement to prevent smothering with silt (Hall-Spencer, 1998). Therefore, maerl beds are restricted to areas of strong tidal currents or wave oscillation (Birkett *et al.* 1998a). For example, Birkett *et al.* (1998a) quote a flow rate of 0.1 m/s across the maerl bed at spring tides in Greatman's Bay, Galway, while the UK biotope classification (Connor *et al.*, 2004) reports maerl beds occurring at sites with between moderately strong to very weak tidal streams. As Birkett *et al.* (1998a) note, local topography and wave generated oscillation probably result in stronger local currents at the position of the bed. Hall-Spencer *et al.* (2006) reported that maerls beds in the vicinity of fish farms became silted with particulates from fish farms even in areas of strong flow. Hall-Spencer *et al.* (2006) reported peak flow rates of 0.5 to 0.7 m/s at the sites studied, and one site experienced mean flows of 0.11 to 0.12 m/s and maxima of 0.21 to 0.47 m/s depending on depth above the seabed.

Sensitivity assessment. An increase in water flow to strong or very strong may winnow away the surface of the bed and result in loss of the biotope. A decrease in water flow may result in increased siltation, smothering maerl, and causing the death of maerl and significant change in the associated community (see smothering/siltation below). The effect will depend on local hydrography and the wave climate. A change of 0.1-0.2 m/s may have a limited effect in areas of moderately strong flow but may be significant in areas of weak or negligible flow. Hall-spencer (pers. comm.) noted that any change in water flow is likely to affect maerl beds. Therefore, a resistance of **'Low'** is suggested but with 'Low' confidence. Hence, as resilience is likely to be **'Very low'**, sensitivity is assessed as **'High'.**

Emergence regime changes	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

In the UK, maerl beds do not occur in the intertidal, as maerl is highly sensitive to desiccation (Wilson *et al.*, 2004). Also, it is very unlikely that a maerl bed would be exposed at low water as a result of human activities or natural events (Tyler-Walters, 2013). Therefore, this pressure is probably 'Not relevant'.

Wave exposure changes (local)	High	High	Not sensitive
	Q: High A: Medium C: Medium	Q: High A: High C: High	Q: High A: Medium C: Medium

Maerl requires enough water movement to prevent smothering with silt (Hall-Spencer, 1998). Therefore, maerl beds develop in strong currents but are restricted to areas of low wave action. For example, in Mannin Bay dense maerl beds were restricted to less wave exposed parts of the bay (Birkett *et al.*, 1998a). In Galway Bay, Keegan (1974) noted the formation of ripples due to wave action and storms, where the ripples were flattened over time by tidal currents. However, he reported that the rippled area (average crest height 20 cm) had a poor faunal diversity with heavy macroalgal settlement on any firm substratum, including the tubes of *Chaetopterus* sp. However, the infauna was a typical '*Venus*' community, the majority of which was found at depths of more than 20 cm. Hall-Spencer & Atkinson (1999) noted that mega-ripples at their wave exposed site were relatively stable but underwent large shifts due to storms. However, the mixed sediments of the subsurface of the bed (>12 cm) were unaffected so that the burrows of the mud shrimp remained in place. Similarly, Birkett *et al.* (1998a) noted that in areas where storms affected the maerl at a depth of 10 m, only the coarse upper layer of maerl was moved while the underlying layers were stable. Following storms, infaunal species renewed burrow linings within a week. However, the epiflora of maerl beds was severely disturbed by storms in Galway Bay with a marked drop in abundance in winter months. Deep beds are less likely to be affected by an increase in wave exposure.

Sensitivity assessment. Maerl beds occur in a range of wave exposures and can survive in areas subject to wave action and storms. Therefore, an increase in wave exposure is probably detrimental to shallow maerl beds. Similarly, a decrease in wave action may be detrimental where wave action is the main contribution to water movement through the bed, due to the potential increase of siltation and reduction in infaunal diversity. However, a 3-5% change in significant wave height is unlikely to damage the maerl bed. Both resistance and resilience are assessed as **'High',** and the biotope is assessed as **'Not sensitive'** to this pressure at the benchmark.

⚗ Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Hydrocarbon & PAH contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Synthetic compound contamination	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

| Radionuclide contamination | No evidence (NEv)
Q: NR A: NR C: NR | Not relevant (NR)
Q: NR A: NR C: NR | No evidence (NEv)
Q: NR A: NR C: NR |

No evidence.

| Introduction of other substances | Not Assessed (NA)
Q: NR A: NR C: NR | Not assessed (NA)
Q: NR A: NR C: NR | Not assessed (NA)
Q: NR A: NR C: NR |

This pressure is **Not assessed**.

| De-oxygenation | Low
Q: High A: High C: Medium | Very Low
Q: High A: Medium C: High | High
Q: High A: Medium C: Medium |

Deoxygenation at the benchmark level is likely to be detrimental to the maerl beds and their infaunal community but mitigated. Water flow experienced by these biotopes suggests that deoxygenating conditions may be short-lived. However, Hall-Spencer *et al.* (2006) examined maerl beds in the vicinity of fish farms in strongly tidal areas. They noted a build-up of waste organic materials up to 100 m from the farms examined and a 10-100 fold increase in scavenging fauna (e.g. crabs). In the vicinity of the farm cages, the biodiversity was reduced, particularly of small crustaceans, with significant increases in species tolerant of organic enrichment (e.g. *Capitella*). In addition, they reported less live maerl around all three of the fish farm sites studied than the 50-60% found at reference sites. Most of the maerl around fish farms in Orkney and South Uist was dead and clogged with black sulphurous anoxic silt. The Shetland farm had the most live maerl but this was formed into mega-ripples, indicating that the maerl had been transported to the site by rough weather (Hall-Spencer *et al.*, 2006).   Eutrophication resulting from aquaculture is cited as one reason for the decline of maerl beds in the North East Atlantic (Hall-Spencer *et al.*, 2010). In the laboratory, Wilson *et al.* (2004) noted that burial in black muddy sand, smelling of hydrogen sulphide, was fatal to live maerl. Even thalli placed on the surface of the black muddy sand died within two weeks, together with thalli buried by 0.25 cm and 2 cm of the sediment (Wilson *et al.*, 2004). A study of a phytoplankton bloom that killed herring eggs on a maerl bed in the Firth of Clyde found that the resultant anoxia caused mass mortalities of the burrowing infauna (Napier, in press, cited by Hall-Spencer pers comm.).

Sensitivity assessment. The available evidence suggests that maerl and its associated community is sensitive to the effects of deoxygenation and anoxia, even in areas of strong water movement. Therefore, resistance has been assessed as **'Low',** resilience as **'Very low',** and sensitivity is assessed as **'High'**.

| Nutrient enrichment | Not relevant (NR)
Q: NR A: NR C: NR | Not relevant (NR)
Q: NR A: NR C: NR | Not sensitive
Q: NR A: NR C: NR |

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The nutrient enrichment of a marine environment leads to organisms no longer being limited by the availability of certain nutrients. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) decreases in dissolved oxygen and uncharacteristic microalgal blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta-analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as a contaminant, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. None of the 47 papers considered the impact of nutrients on this biotope. Yet this finding is still relevant as the meta-analysis revealed that the effect of marine pollutants on species diversity was 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation, there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However research into the impacts of nutrient enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

Grall & Glemarec (1997) noted that increased turbidity and eutrophication due to agricultural runoff in Brittany prevented the establishment of many algal species resulting in domination of ubiquitous species (e.g. *Ceramium* sp. and *Ulva* sp.), while localised eutrophication due to fish and mussel farming (aquaculture) in a sheltered area resulted in bacterial mats of *Beggiatoa*. Hall-Spencer *et al.* (2006) examined maerl beds in the vicinity of fish farms in strongly tidal areas. They noted a build-up of waste organic materials up to 100 m from the farms examined and a 10-100 fold increase in scavenging fauna (e.g. crabs). In the vicinity of the farm cages, the biodiversity was reduced, particularly of small crustaceans, with significant increases in species tolerant of organic enrichment (e.g. *Capitella*). In addition, they reported less live maerl around all three of the fish farm sites studied than the 50-60% found at reference sites. Most of the maerl around fish farms in Orkney and South Uist was dead and clogged with black sulphurous anoxic silt (Hall-Spencer *et al.*, 2006). Eutrophication resulting from aquaculture is cited as one reason for the decline of some beds in the North East Atlantic (Hall-Spencer *et al.*, 2010).

In Brittany, numerous maerl beds were affected by sewage outfalls and urban effluents, resulting in increases in contaminants, suspended solids, microbes and organic matter with resultant deoxygenation (Grall & Hall-Spencer, 2003). This resulted in increased siltation, higher abundance and biomass of opportunistic species, loss of sensitive species and reduction in biodiversity. Grall & Hall-Spencer (2003) note that two maerl beds directly under sewage outfalls were converted from dense deposits of live maerl in the 1950s to heterogeneous mud with maerl fragments buried under several centimetres of fine sediment with species poor communities. These maerl beds were effectively lost.

Sensitivity assessment. The effect of eutrophication on maerl beds is difficult to disentangle from the effects of organic enrichment, and sedimentation. It is likely that nutrient enrichment could adversely affect the infauna and epiflora communities but the direct effect on maerl is unclear. Nevertheless, the biotope is **'Not sensitive'** at the pressure benchmark of compliance with good status as defined by the WFD.

Organic enrichment	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

The organic enrichment of a marine environment at this pressure benchmark leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in

ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) and decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008). Grall & Hall-Spencer (2003) considered the impacts of eutrophication as a major threat to maerl beds.

Hall-Spencer *et al.* (2006) compared maerl beds under salmon farms with reference maerl beds. It was found that maerl beds underneath salmon farms had visible signs of organic enrichment (feed pellets, fish faeces and/or *Beggiatoa* mats), and significantly lower biodiversity. At the sites underneath the salmon nets, there were 10 – 100 times the number of scavenging species present compared to the reference sites. Grall & Glémarec (1997) noted similar decreases in maerl bed biodiversity due to anthropogenic eutrophication in the Bay of Brest. In Brittany, numerous maerl beds were affected by sewage outfalls and urban effluents, resulting in increases in contaminants, suspended solids, microbes and organic matter with resultant deoxygenation (Grall & Hall-Spencer, 2003). This resulted in increased siltation, higher abundance and biomass of opportunistic species, loss of sensitive species and reduction in biodiversity. Grall & Hall-Spencer (2003) note that two maerl beds directly under sewage outfalls were converted from dense deposits of live maerl in the 1950s to heterogeneous mud with maerl fragments buried under several centimetres of fine sediment with species poor communities. These maerl beds were effectively lost.

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Sensitivity assessment. Little empirical evidence was found to directly compare the benchmark organic enrichment of maerl biotopes. However, the evidence strongly suggests that organic enrichment and resultant increased in organic content, hydrogen sulphide levels and sedimentation may result in loss of maerl beds. Resistance is assessed as **'None'** and resilience assessed as **'Very low'** so that sensitivity is assessed as **'High'.**

⚑ Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of **'None'** to this pressure and to be unable to recover from a permanent loss of habitat (resilience is **'Very Low'**). Sensitivity within the direct spatial footprint of this pressure is, therefore **'High'**. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

	Resistance	Resilience	Sensitivity
Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

Maerl biotopes can contain a variety of sediment types including gravels, sand and mud. However, maerl biotopes never contain bedrock. Therefore, if rock or an artificial substrate was to replace

the normal substratum within this biotope the physical conditions required for this biotope would be lost along with the biotope itself. Therefore, resistance is likely to be **'None'**, resilience **'Very Low'** (permanent change) and sensitivity is assessed as '**High**'.

Physical change (to another sediment type)	High	High	Not sensitive
	Q: High A: High C: High	Q: High A: High C: High	Q: High A: High C: High

The sediment associated with maerl biotopes varies from shell and maerl gravel through to sand and mud. The characterizing maerl species is also not attached to the substratum, and instead lies over the top of it. Therefore, if the substratum were to change this wouldn't have a negative effect on the characterizing species. The other species within the associated community depend on different aspects of the sediment. Those species which are found infaunally may be negatively affected.

Sensitivity assessment. A change in this pressure at the benchmark will not affect the characterizing species yet may affect other species found infaunally within the biotope. The loss of an infaunal species will create a niche for another species to become established, therefore continuing the biological function and ensuring the character of the biotope remains. Resistance and resilience are assessed as **'High'**, and sensitivity as **'Not Sensitive'**.

Habitat structure changes - removal of substratum (extraction)	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

As maerl need to photosynthesise only the top layer of the deposit which has access to light will be alive. Live maerl also requires good water flow around it, a factor which is likely to be limited 30 cm into the bed. Maerls requirement for both light and water flow suggest that the majority if not all of the live maerl will be found in the top 30 cm of a maerl bed. This is also where many of the associated species will be found. Although long-lived elements of maerl bed fauna are known to burrow up to 72 cm into the substrate (Hall-Spencer & Atkinson, 1999). The extraction of the substratum to 30 cm within this biotope would remove the vast majority of the biological component of the biotope.

Hauton *et al.* (2003) undertook experimental suction (hydraulic dredging) in Stravanan Bay, Scotland, a site subject to scallop dredging and recorded as impacted dead maerl by Kamenos *et al.* (2003). The suction dredge removed epiflora (burrowing algae and macroalgae), maerl, slow-moving epifauna (e.g. starfish, gastropods and clingfish) and mainly infauna. Large or fragile polychaetes (e.g. *Chaetopterus*) and *Cerianthus lloydii* were removed and damaged, while polychaetes with tough bodies or strong tubes survived. Large infaunal bivalves dominated the catch, including *Dosinia exoleta, Tapes rhomboides, Abra alba*, and *Ensis arcuatus* but, while *Mya truncata and Lutraria angustior* were not caught because of their depth, the catch did include torn siphons from these species; an injury they are unlikely to survive. The dredge resulted in a visible track that left numerous damaged megafauna, which in turn attracted scavengers. In addition, the dredging fragmented maerl and resulted in a large plume of fine sediment that settled over the surrounding area. However, recovery was not examined. Hall-Spencer *et al.* (2003) drew attention to the dangers of suction dredging for bivalves in maerl beds, especially as many of the larger infaunal bivalves are long-lived (e.g. *Dosinia exoleta*), suggesting that the population would take a long time to recover.

Sensitivity assessment. The resistance of the biotope to this pressure at the benchmark is assessed as **'None'**, the resilience as **'Very low',** and sensitivity assessed as 'High'.

Abrasion/disturbance of the surface of the substratum or seabed	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

Physical disturbance can result from; channelization (capital dredging), suction dredging for bivalves, extraction of maerl, scallop dredging or demersal trawling. The effects of physical disturbance were summarised by Birkett *et al.* (1998a) and Hall-Spencer *et al.* (2010), and documented by Hall-Spencer and co-authors (Hall-Spencer, 1998; Hall-Spencer *et al.*, 2003; Hall-Spencer & Moore, 2000a, b; Hauton *et al.*, 2003; and others). For example, in experimental studies, Hall-Spencer & Moore (2000a, c) reported that the passage of a single scallop dredge through a maerl bed could bury and kill 70% of living maerl in its path. The passing dredge also re-suspended sand and silt that settled over a wide area (up to 15 m from the dredged track), and smothered the living maerl. The dredge left a 2.5 m track and damaged or removed most megafauna within the top 10 cm of maerl (Hall-Spencer & Moore, 2000a). For example; crabs, *Ensis* species, the bivalve *Laevicardium crassum*, and sea urchins. Deep burrowing species such as the tube anemone *Cerianthus lloydii* and the crustacean *Upogebia deltaura* were protected by depth, although torn tubes of *Cerianthus lloydii* were present in the scallop dredge tracks (Hall-Spencer & Moore, 2000a). *Neopentadactyla mixta* may also escape damage due to the depth of its burrow, especially during winter torpor. Hall-Spencer & Moore (2000a) reported that sessile epifauna or shallow infauna such as *Modiolus modiolus* or *Limaria hians*, sponges and the anemone *Metridium senile* where present, were significantly reduced in abundance in dredged areas for 4 years post-dredging. Other epifaunal species, such as hydroids (e.g. *Nemertesia* species) and red seaweeds are likely to be removed by a passing dredge. The tracks remained visible for up to 2.5 years. In pristine live beds, experimental scallop dredging reduced the population densities of epibenthic species for over 4 years. However, in previously dredged maerl beds, the benthic communities recovered in 1-2 years.

Abrasion may break up maerl thalli into smaller pieces resulting in easier displacement by wave action, resulting in a reduced structural heterogeneity and lower diversity of species (Kamenos *et al.*, 2003). Hall-Spencer *et al.* (2003) noted that certain maerl beds in the Bay of Brest have been dredged for scallops and *Venus verrucosa* for over 40 years, yet remain productive with high levels of live maerl. Although they suggest that this is due to local restrictions that limit the activity to one scallop dredge per boat. Nevertheless, scallop dredging, demersal trawling and extraction have been reported to contribute to declines in the condition of maerl beds in the North East Atlantic and the UK (Barbera *et al.*, 2003, Hall-Spencer *et al.*, 2010, Hall-Spencer *et al.*, 2003). Irish maerl are considered to be in generally good condition but some are deteriorating due to commercial extraction, mariculture, demersal fishing and the localized effects of boat mooring chains (Vize, 2005).

Sensitivity assessment. Physical disturbance is likely to result in drastic changes in and loss of components of the community within the maerl bed. Fragmentation of the maerl will not kill the maerl directly but subsequent death is likely due to a reduction in water flow caused by compaction and sedimentation (Hall-spencer & Moore, 2000a; 2000c). Dredging can create plumes of sediment that can settle on top of the maerl, and overturn and bury maerl, causing it to be smothered, a pressure to which maerl is highly intolerant (see smothering and siltation (light) pressure). The evidence from Hall-Spencer & Moore (2000a; 2000 c) alone strongly suggests that

resistance to physical disturbance and abrasion is **'None'**. Therefore, resilience is probably **'Very low'**, resulting in a sensitivity assessment of **'High'**.

Penetration or disturbance of the substratum subsurface	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

As maerl need to photosynthesise only the top layer of the deposit which has access to light will be alive. Live maerl also requires good water flow around it. Maerl beds become less structurally complex if they have been affected by dredging (Kamenos *et al.*, 2003). A lack of structural complexity will restrict the niches for other species, reducing biodiversity and will also restrict water flow through the bed. Penetration and disturbance both have the capacity to break up maerl into smaller fragments. The evidence provided within the abrasion and disturbance pressure shows that maerl is intolerant of abrasion. Penetration of the maerl bed will exacerbate the negative effect by damaging more of the underlying maerl.

Sensitivity assessment. Based on the evidence provided within the abrasion and disturbance assessment the resistance of the biotope to this pressure at the benchmark is considered **'None'** and the resilience is assessed as **'Very low'**, giving the biotope a **'High'** sensitivity.

Changes in suspended solids (water clarity)	Medium	Very Low	Medium
	Q: Medium A: Medium C: Medium	Q: High A: Medium C: High	Q: Medium A: Medium C: Medium

Maerl's requirement for light restricts them to depths shallower than 32 m in the relatively turbid waters of northern Europe (Hall-Spencer, 1998). An increase in suspended sediments in the water column will increase light attenuation and decrease the availability of light to the biotope. A decrease in light availability will alter the ability of the maerl to photosynthesise. This could be detrimental to maerl beds found towards the bottom depth limit in Europe (i.e. 32 m). An increase in suspended solids within this biotope is likely to also increase scour, as there are characteristically high levels of water movement through maerl beds. Scour is known to induce high mortality in early post-settlement algal stages and prevents the settlement of propagules owing to the accumulation of silt on the substratum (Vadas *et al.*, 1992). Increased particulates may provide additional food for filter feeders. However, an increase in suspended sediment may increase the fines within the bed, decreasing water flow and oxygenation through the bed, and hence the depth of the surface epifauna. It may result in an increase in burrowing species compared to filter feeding species. However, De Grave (1999) noted that sedimentary heterogeneity within maerl beds (including maerl debris with mud, sand or gravel) resulted in only minor changes in the community of amphipods and crustaceans present.

A decrease in suspended solids will increase light levels, which could benefit maerl. However, a decrease in suspended matter is likely to reduce the quantity of food available for filter feeders. This could lead to a minor change species present within the community but is unlikely to cause a major shift in the biotope.

Sensitivity assessment. Any factor which decreases the ability for the characterizing maerl species to photosynthesise will have a negative impact. Examples of the biotope found at the very bottom depth limit may experience high levels of mortality of the characterizing species. The resistance of this biotope is assessed as **'Medium'** and the resilience is **'Very low'.** Hence, the sensitivity is assessed as **'Medium'** to the pressure at the benchmark level.

Smothering and siltation rate changes (light)	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

Smothering results from the rapid deposition of sediment or spoil, which may occur after dredging (suction or scallop), capital dredging (channelization), extreme runoff, spoil dumping etc. The effects depend on the nature of the smothering sediment. For example, live maerl was found to survive burial in coarse sediment (Wilson *et al.*, 2004) but to die in fine sediments. *Phymatolithon calcareum* survived for 4 weeks under 4 and 8 cm of sand or gravel but died within 2 weeks under 2 cm of muddy sand. Wilson et al. (2004) suggested that the hydrogen sulphide content of the muddy sand was the most detrimental aspect of burial since even those maerl nodules on the surface of the muddy sand died within two weeks. They also suggested that the high death rate of maerl observed after burial due to scallop dredging (Hall-Spencer & Moore, 2000a,c) was probably due to physical and chemical effects of burial rather than a lack of light (Wilson *et al.*, 2004).

In addition, detrimental effects on *Fucus* embryos were reported in fine sediments, presumably as fine sediment restricts water flow. Similarly, fine sediment is likely to prevent settlement of algal propagules, so that the effects are potentially greater during their settlement period. Kranz (1972; cited in Maurer *et al.* (1986) reported that shallow burying siphonate suspension feeders are typically able to escape smothering with 10-50 cm of their native sediment and relocate to their preferred depth by burrowing. Dow & Wallace (1961) noted that large mortalities in clam beds resulted from smothering by blankets of algae (Ulva sp.) or mussels (*Mytilus edulis*). In addition, clam beds have been lost due to smothering by 6 cm of sawdust, thin layers of eroded clay material, and shifting sand (moved by water flow or storms) in the intertidal.

Smothering by 5cm of sediment (the benchmark) is likely to clog or reduce water flow through the surface of the bed, and directly smother small non-mobile members of the epifauna and epiflora, while larger species e.g. sea squirts, anemones, some sponges and macroalgae would protrude above the smothering sediment. Mobile small burrowing species (e.g. amphipods and polychaetes) would probably burrow to safety. However, non-motile epifauna (e.g. encrusting bryozoans and small hydroids) and small or prostrate algal will probably be reduced in abundance. Deep burrowing bivalves may experience some mortality due to loss of water flow through the bed, deoxygenating and lack of food depending on their depth. But large burrowing anemones and mud shrimp would probably just burrow through the smothering material. In Galicia, France, ongoing deterioration of maerl has been linked to mussel farming which increases sedimentation, reducing habitat complexity, lowering biodiversity, and killing maerl (Pena & Barbara, 2007a, b; cited in Hall-Spencer *et al.*, 2010). Wilson *et al.* (2004) also point out that the toxic effect of fine organic sediment and associated hydrogen sulphide explain the detrimental effect on maerl beds of *Crepidula fornicata* in Brittany, sewage outfalls, and aquaculture (Grall & Hall-spencer, 2003).

Sensitivity assessment. Even though these biotopes occur in areas of tidal or wave mediated water flow, the fine smothering material would penetrate the open matrix of the maerl bed rather than sit on top of the bed. At the pressure benchmark this biotope's resistance is assessed as **'None',** and the resilience as '**Very low**' so that sensitivity is assessed as **'High'.**

Smothering and siltation rate changes (heavy)	None	Very Low	High
	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

A deposit at the pressure benchmark would cover all species with a thick layer of fine materials. The pressure is significantly higher than light smothering discussed above. Therefore, resistance is

assessed as assessed as **'None',** the resilience as '**Very low**', and sensitivity is assessed as **'High'.**

Litter	Not Assessed (NA)	Not assessed (NA)	Not assessed (NA)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

No evidence.

Underwater noise changes	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Species characterizing this habitat do not have hearing perception but vibrations may cause an effect, however, no studies exist to support an assessment.

Introduction of light or shading	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Maerl forming species require light, which restricts them to depths shallower than 32m in the relatively turbid waters of northern Europe (Hall-Spencer, 1998). Suggesting that maerl is intolerant of long-term reductions in light availability. However, in the short-term maerl exhibits little stress after being kept in the dark for 4 weeks (Wilson *et al.*, 2004).

Sensitivity assessment. Artificial light is unlikely to affect any but the shallowest biotopes. There is a possibility that shading by artificial structures could result in the loss of live maerl in deep examples of the biotope, but only where shading was long-term or permanent. There is insufficient information to assess the effect of this pressure at the benchmark on this biotope. The sensitivity of this biotope is given as 'No evidence'.

Barrier to species movement	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant – this pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit propagule dispersal. But propagule dispersal is not considered under the pressure definition and benchmark.

Death or injury by collision	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion'.

Visual disturbance	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Not relevant.

🐚 Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR)	Not relevant (NR)	Not relevant (NR)
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

This pressure is not relevant to the characterizing species within this biotope.

	None	Very Low	High
Introduction or spread of invasive non-indigenous species	Q: High A: High C: High	Q: High A: Medium C: High	Q: High A: Medium C: High

No evidence of the effects of non-native species in the UK was found. However, Grall & Hall-spencer (2003) note that beds of invasive slipper limpet *Crepidula fornicata* grew across maerl beds in Brittany. As a result, the maerl thalli were killed, and the bed clogged with silt and pseudo-faeces so that the associated community was drastically changed. Bivalve fishing was also rendered impossible. Peña *et al.* (2014) identified eleven invasive algal species found on maerl beds in the North East Atlantic. The invasive species included *Sargassum muticum*, which causes habitat shading (Hall-Spencer pers. comm.).

Sensitivity assessment. Removal of the surface layer of *Crepidula fornicata* is possible but only with the removal of the surface layer of maerl itself, which would be extremely destructive on live beds. A resistance of **'None'** and a resilience of **'Very low'** has been given, resulting in an overall sensitivity assessment of **'High'**.

	No evidence (NEv)	Not relevant (NR)	No evidence (NEv)
Introduction of microbial pathogens	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

Coralline lethal orange disease found in the Pacific and could have devastating consequences for maerl beds in Europe. However, this disease was not known to be in Europe (Birkett *et al.*, 1998a). Many of the species that make up the biological community within this biotope will be susceptible to disease in the form of viruses or parasites. However, 'No evidence' of the effects of diseases and pathogens on maerl beds was found.

	None	Very Low	High
Removal of target species	Q: High A: High C: Medium	Q: High A: Medium C: High	Q: High A: Medium C: Medium

Maerl is mainly sold dried as a soil additive but is also used in animal feed, water filtration systems, pharmaceuticals, cosmetics and bone surgery. Maerl beds are dredged for scallops (found in high densities compared with other scallop habitats) where extraction efficiency is very high. This harvesting has serious detrimental effects on the diversity, species richness and abundance of

maerl beds (Hall-spencer & Moore, 2000c).

Within Europe, there is a history of the commercial collection and sale of maerl. Two notable sites from western Europe which from which Maerl has been collected are off the coast of Brittany, where 300,000 – 500,000 t / annum are dredged (Blunden, 1991), and off Falmouth Harbour in Cornwall where extraction is around 20,000 t / annum (Martin, 1994; Hall-Spencer, 1998).

Kamenos *et al.* (2003) reported that maerl grounds impacted by towed demersal fishing gears are structurally less heterogeneous than pristine, un-impacted maerl grounds, diminishing the biodiversity potential of these habitats. Birkett *et al.* (1998a) noted that although maerl beds subject to extraction in the Fal estuary exhibit a diverse flora and fauna, they were less species-rich than those in Galway Bay, although direct correlation with dredging was unclear. Grall & Glemarec (1997; cited in Birkett *et al.*, 1998a) reported few differences in biological composition between exploited and control beds in Brittany. Dyer & Worsfold (1998) showed differences in the communities present in exploited, previously exploited and unexploited areas of maerl bed in the Fal Estuary but it was unclear if the differences were due to extraction or the hydrography and depth of the maerl beds sampled. In Brittany, many of the maerl beds are subject to extraction (Grall & Hall-Spencer, 2003). For example, the clean maerl gravel of the Glenan maerl bank described in 1969, was degraded to muddy sand dominated by deposit feeders and omnivores within 30 years. Grall & Hall-Spencer (2003) noted that the bed would be completed removed within 50-100 years at the rates reported in their study. Hall-Spencer *et al.* (2010) note that maerl extraction was banned in the Fal in 2005.

The other species of commercial interest found within maerl beds are scallops, for which there are two methods of capture for these organisms. Firstly the use of a scallop dredge the effect of which is assessed under the abrasion and disturbance pressure. The second method of removal is diver collection. There is no evidence to suggest that there is a symbiotic relationship between maerl and scallops. Consequently, the removal of this species is unlikely to have a significant effect on the health of the biotope.

Sensitivity assessment. Maerl itself has historically been targeted for commercial collection. The removal of this characterizing species is highly destructive for this biotope and the resistance is assessed as **'None'**, and the resilience is assessed as **'Very low',** giving a sensitivity assessment of **'High'**. However, the practice of removing maerl for industry is now banned in places such as the Fal.

Removal of non-target species	Low	Very Low	High
	Q: High A: High C: Medium	Q: High A: Medium C: High	Q: High A: Medium C: Medium

Direct, physical impacts from harvesting are assessed through the 'abrasion' and 'penetration of the seabed' pressures above. The extraction of maerl itself, scallop dredging for scallops and/or suction dredging for other commercially exploited shellfish would also damage other members of the community. For example, the red seaweed community is likely to be damaged or removed at the surface, and interstitial bivalves damaged within or removed from the bed. The loss of these species and other associated species would decrease species richness and negatively impact on the ecosystem function.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope. The resistance to removal is **'Low'** due to the easy accessibility of the biotopes location and the inability of these species to evade collection. The resilience is **'Very low'**,

with recovery only being able to begin when the harvesting pressure is removed altogether. This gives an overall sensitivity score of **'High'**.

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