Ceramium sp. and piddocks on eulittoral fossilised peat

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

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Piddock bored rock with red algae.
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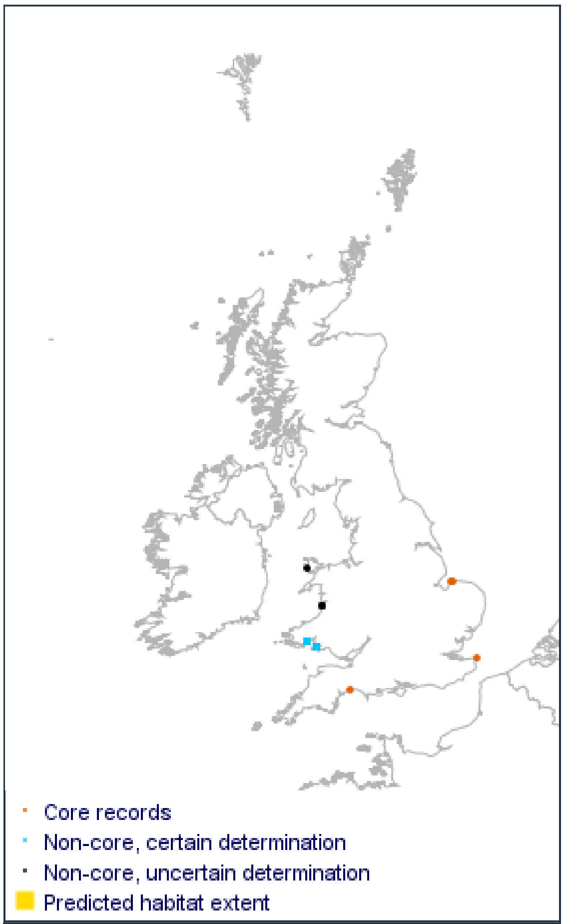

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Georgina Budd **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.127	*Ceramium* sp. and piddocks on eulittoral fossilised peat
JNCC 2015	LR.HLR.FR.RPid	*Ceramium* sp. and piddocks on eulittoral fossilised peat
JNCC 2004	LR.HLR.FR.RPid	*Ceramium sp.* and piddocks on eulittoral fossilised peat
1997 Biotope	LR.MLR.R.RPid	*Ceramium sp.* and piddocks on eulittoral fossilised peat

Description

Outcrops of fossilized peat in the eulittoral are soft enough to allow a variety of piddocks (such as *Barnea candida* and *Petricola pholadiformis*) to bore into them. The surface of the peat is characterized by a dense algal mat, predominantly *Ceramium* spp. but also with *Ulva* spp. and *Polysiphonia* spp. Damp areas amongst the algal mat are covered by aggregations of the sand mason worm *Lanice conchilega* and the fan worm *Sabella pavonina*. The anemone *Sagartia troglodytes* and the crabs *Carcinus maenas* and *Cancer pagurus* occur in crevices in the peat. Small pools on the peat may contain hydroids, such as *Obelia longissima* and *Kirchenpaueria pinnata*, the brown alga *Dictyota dichotoma* and the prawn *Crangon crangon*.(Connor *et al*., 2004; JNCC)

Depth range

-

Additional information

No text entered.

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- Little information was found concerning the community of this biotope.
- All boring piddocks begin excavation following settling of the larva and slowly enlarge and deepen the burrow with growth (Pinn *et al*., 2005). They are forever locked within their burrows, and only the siphons project to the surface opening (Barnes, 1980). A relationship exists between the distribution of piddock species and substratum type. Duval (1963a) examined the penetrability of a variety of substrata by *Petricola pholadiformis*. It may bore into London Clay, Thanet Sandstone, softer chalk and peaty substrata. It was unable to bore into abnormally hard clays, soft loose mud, shifting sand, gritty and Lower Greensand Gault clay, hard chalk and Blue Lower Lias. Thus its distribution is determined by changes in the substratum of the shore rather than by tidal level (the piddock may flourish from extreme low water to mid-tide level).
- Hydroids living in pools in the peat are opportunistic carnivores mainly catching suspended plankton as food.
- Filter / suspension feeding organisms such as the piddocks, *Barnea candida* and *Petricola pholadiformis*; the peacock worm, *Sabella pavonina* and sand mason worm, *Lanice conchilega*, are the dominant trophic group in the biotope, indicating the importance of planktonic inputs to the community. Piddocks probably contribute to the creation of a relatively high silt environment through burrowing activities.
- Crabs, such as *Carcinus maenas* and *Cancer pagurus*, are the predominant mobile species in the biotope, travelling through as they scavenge for food.
- The anemone, *Sagartia troglodytes*, which may occur in crevices of the peat, uses 'catch tentacles to prey upon small shrimps and crabs. In turn, *Sagartia troglodytes* is preyed upon by the grey sea slug, *Aeolidia papillosa*, and attacked by the tompot blenny, *Parablennius gattorugine* (BMLSS, 2002c) that may frequent the biotope
- Algae that grows on the surface of the peat may provide shelter for small crustaceans and possibly a source of food for grazing prosobranchs, such as *Littorina littorea*, which may occasionally occur in the biotope but is not characteristic.
- Species of isopod and amphipod may also feed on detrital matter within the dense algal mat and prey upon each other.

Seasonal and longer term change

- One of the characteristic species of this biotope, *Petricola pholadiformis*, has a longevity of up to 10 years (Duval, 1963a) and whose established populations may not exhibit significant seasonal changes, besides spawning in the summer. Variations in the abundance and seaweed species present would be expected to vary between and within locations according to the season. For instance, following storms, the peat may be covered by a layer of sand which could adversely affect the surface of algal species, especially propagules.

Habitat structure and complexity

Outcrops of fossilized peat in the eulittoral may project above sand level by > 15 cm and form extensive platforms up to 100 m in length across the shore. Fossilized peat tends to be firm and relatively erosion resistant (Murphy, 1981), and occur in localities backed by extensive beach and dune systems, so that the patches of peat exposed varies according to sand movement. The peat is likely to have pits, crevices and undulations in surface level in addition to vacant piddock burrows. Empty piddock burrows can influence the abundance of other species by providing additional habitats and refuges. For instance, Pinn *et al.* (in press) found a statistically significant increase in species diversity in areas where old piddock burrows were present compared to where they were absent. Pools of water may accumulate in surface depressions which favour hydroids (e.g. *Obelia longissima* and prawns such as *Crangon crangon*). The covering of red and ephemeral green algae probably provide cover for cryptic fauna.

Productivity

Algal species, *Ceramium*, *Ulva*, form a characteristic mat over the surface of the peat substratum so primary production is a component of productivity. Many of the characterizing species that are present in the biotope are suspension/filter feeders, so productivity of the biotope would probably be largely dependent on detrital input. However, specific information about the productivity of characterizing species or about the biotope in general was not found.

Recruitment processes

Most of the characterizing species in the biotope are sessile or sedentary. Consequently, recruitment must occur primarily through dispersive larval or spore stages. Examples of characterizing species are given below.

- Duval (1963a) reviewed the biology of *Petricola pholadiformis*. The sexes of *Petricola pholadiformis* are separate. Females are estimated to produce between 3,000,000 and 3,500,000 eggs annually. Gametogenesis takes place between April and early June and a waiting period ensues before spawning occurs towards late July and during August, lasting just over six weeks in total. The juvenile trochophore stage is reached within 28 hours, and the veliger stage in 44 hours. Length of planktonic life was estimated to be in the region of only one and a half to two weeks in duration, after which the young *Petricola pholadiformis* assume a benthic lifestyle, but remain extremely active. Juveniles of 0.4 cm length possess a very strongly ciliated and mobile foot and large amounts of mucus aid adherence to the substratum. Shell growth may begin in April or during May and continues until after June. Thereafter, growth rings are laid down annually, and annual growth in younger specimens is in the region of 0.7 - 0.9 cm.
  Similarly, the white piddock, *Barnea candida*, has separate sexes and fertilization occurs externally (Duval, 1963b). Many bivalves spawn during the part of the year when sea temperatures are rising. No information was found concerning length of planktonic life in *Barnea candida* but El-Maghraby (1955) showed that in southern England *Barnea candida* spawned in September, being unusual that it started to spawn when the temperature fell at the beginning of the autumn. The maximum age estimated for *Barnea candida* is 4 years with growth rates ranging from 0.1-6.8 mm per year (Pinn *et al.*, 2005).
- Edwards (1973) reported that the red seaweed, *Ceramium virgatum* (as *Ceramium nodulosum*), has a triphasic life history consisting of a sequence of gametophytic, carposporophytic and tetrasporophytic phases in which the first and the third are morphologically similar. Maggs & Hommersand (1993) reported spermatangia in

    January, March-April, June and August-September; cystocarps in January-February and April-September; tetrasporangia in February-September. Although no information on dispersal has been found directly for *Ceramium virgatum*, Norton (1992) concluded that dispersal potential is highly variable in seaweeds, but recruitment probably occurs on a local scale, typically within 10m of the parent plant.
  - The green seaweed, *Ulva* is considered to be opportunistic in its colonization of available substrata, its rapid recruitment made feasible by its life cycle, which consists of both sexual and asexual generations. Reproduction can occur throughout the year, but is maximal in summer. The haploid gametophytes (arising from sexual reproduction) of *Ulva* produce enormous numbers of motile gametes that fuse and germinate to produce sporophytes. Sporophytes also produce large numbers of motile spores that are released in such great numbers that the water can become green (Little & Kitching, 1996). The dispersal potential of such spores is great (> 10 km) so that the species may recruit from distant populations.
  - Hydroids, such as *Obelia longissima*, are often the first organisms to colonize available space in settlement experiments (Gili & Hughes, 1995). The hydroid phase of *Obelia longissima* releases dioecious sexual medusae that swim for up to 21 days (Sommer, 1992) and release sperm or eggs into the sea (fertilization is external). The resultant embryos then develop into planulae larvae that swim for 2-20 days (Sommer, 1992). Therefore, their potential dispersal is much greater than those species that only produce planulae. In addition, few species of hydroids have specific substratum requirements and many are generalists, for example *Obelia longissima* has been reported from a variety of rock and mud substrata.

Time for community to reach maturity

Little information was found concerning community development. However, piddocks, *Barnea candida* and *Petricola pholadiformis* are likely to settle readily. These piddocks breed annually and produce a large number of gametes. Once established individuals may live for a considerable length of time; *Petricola pholadiformis* of length 5-6 cm are likely to be between 6-10 years old (Duval, 1963a). Another characteristic component of the biotope is the algal mat of *Ceramium* and *Ulva* that caps the peat and development of this algal mat would be expected to be rapid. For instance, panels were colonized by *Ceramium virgatum* (as *Ceramium nodulosum*) within a month of being placed in Langstone Harbour (Brown *et al*., 2001), whilst *Ulva* spp. Are known to colonize available substrata rapidly. *Barnea candida* grows rapily to a length of approximately 25-35 mm within 2 to 3 years, living for a maximum of 4 years (Pinn *et al*., 2005).

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	
Water clarity preferences	
Limiting Nutrients	Field unresearched
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Eulittoral
Substratum/habitat preferences	Peat (fossilized)
Tidal strength preferences	
Wave exposure preferences	Moderately exposed
Other preferences	Fossilized peat.

Additional Information

Further records of this biotope are required.

Species composition

Species found especially in this biotope

- *Barnea candida*
- *Petricola pholadiformis*

Rare or scarce species associated with this biotope

-

Additional information

No text entered.

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is present on fossilised peats, an unusual coastal habitat, which is restricted to a few locations. As the occurrence of piddock biotopes are highly dependent on the presence of suitable substratum, the sensitivity assessments specifically consider the sensitivity of fossilised peats to the pressures, where appropriate. The piddocks associated with the biotope are key characterizing species and if these were removed the biotope classification would change. Piddocks are also important structuring species as their empty holes can provide habitats for other species (Pinn *et al*., 2008) and they are bioeroders, destabilising the substratum through burrowing allowing it to be more easily eroded by water flow and wave action (Pinn *et al*., 2005; Evans, 1968, Trudgill, 1983, Trudgill & Crabtree, 1987). Pinn *et al*. (2005) estimated that over the lifespan of a piddock (12 years), up to 41% of the shore could be eroded to a depth of 8.5 mm).

The sensitivity assessment therefore primarily considers the fossilised peat habitat and piddocks when developing assessments. The common piddock species *Barnea candida*, *Pholas dactylus* and the introduced American piddock *Petricolria pholadiformis* (formerly *Petricola pholadiformis*) are likely to occur in this biotope and the available evidence for each of these has been used to develop the sensitivity assessment. *Ceramium* sp. are named in the biotope description and are therefore also considered characteristic of the biotope and are included in the assessments.

Other species associated with the biotope are commonly found on many different shore types and are either mobile or rapid colonizers. Although these species contribute to the structure and function of the biotope they are not considered key species and are not specifically assessed.

Resilience and recovery rates of habitat

This biotope is present in areas where fossilised peat are exposed at the surface. This habitat type is restricted in distribution and the thickness of the peat layers varies. When removed entirely there is no mechanism by which the substratum can be replaced, unlike other sedimentary habitats which may be renewed by water transport of sediment particles. Where entirely removed, no recovery of habitat is possible and resilience is therefore considered to be 'Very Low' (>25 years).

Ceramium spp. may regenerate from very small fragments of thalli attached to the substratum or the development of germlings from settled spores (Dixon, 1960).*Ceramium virgatum* has been shown to recruit rapidly to cleared surfaces. For instance, experimental panels were colonized by Ceramium virgatum (as *Ceramium nodulosum*) within a month of being placed in both Langstone Harbour (Brown *et al*., 2001) and in the outer harbour of the Isle of Helgoland (Wollgast *et al*., 2008). Resilience of this species has therefore been assessed to be ‘High’ in all instances where suitable habitat is present. Recolonization may, however, be delayed if the hydrodynamic regime does not allow a supply of spores from distant populations when local extirpation occurs.

No direct information for recovery rates of piddocks to perturbations was found and limited information on population dynamics and relevant life history characteristics is available. Adult piddocks remain within permanent burrows and are therefore difficult to observe and sample without destroying the burrows which has limited the extent of observation and experimentation.

The burrowing mechanisms of the piddocks *Pholas dactylus* and *Barnea candida* and other Pholads, mean that the burrows have a narrow entrance excavated by the juvenile. As the individual grows and excavates deeper the burrow widens resulting in a conical burrow from which the adult cannot emerge. *Petricolaria pholadiformis* excavates a cylindrical burrow (Ansell, 1970) and hence may be able to relocate. Burrowing mechanisms have been studied for *Petricolaria pholadiformis* (studied as *Petricola pholadiformis*) individuals placed on sand, chalk and clay (Ansell, 1970). Animals placed on clay and chalk could only reburrow where holes of a suitable size had already been excavated. The relatively slow burial rate means that individuals would be vulnerable to predation when all or parts of the individual are exposed at the substratum surface. As Piddocks are unable to relocate to avoid impacts recovery through migration of adults into an impacted area is not considered possible.

Recovery of impacted populations will depend on recolonization by juveniles. In piddocks the sexes are separate and fertilisation is external, with gametes released into the water column (Pinn *et al*., 2005 and references therein). The fecundity of female *Petricolaria pholadiformis* is estimated to be between 3 - 3.5 million eggs per year (Duval, 1963a). Studies report that larval release occurs from April to September (e.g. Pelseneer, 1924;; El-Maghraby, 1955; Purchon 1955; Duval 1962; Knight 1984). Knight (1984) reported that the resulting planktonic larval stage spends 45 days in the plankton. Pinn *et al*., (2005) observed newly settled individuals between November and February. Pinn *et al*. (2005) found the smallest sexually mature *Pholas dactylus* was a one year old measuring 27.4 mm, information on age at sexual maturity was not reported for other species.

Piddocks are relatively long-lived; *Petricolaria pholadiformis*, has a longevity of up to 10 years (Duval, 1963a) while *Pholas dactylus* lives to an estimated 14 years of age, based on annual growth lines (Pinn *et al*., 2005). The smaller *Barnea candida* has a shorter lifespan of 6 years (estimated from annual growth lines) (Pinn *et al*., 2005). Pinn *et al*., (2005) estimated age and growth rates for *Pholas dactylus*, *Barnea candida* and *Barnea parva* from chalk and clay sites in Southern England. She showed that *Pholas dactylus* are slow growing, whereas *Barnea candida* are fast growing, although shorter lived and hence achieving a smaller final length than *Pholas dactylus*. Jefferies (1865) reported that *Pholas dactylus* in the UK reached a maximum length of 150 mm, although 125 mm was a more usual size encountered, and a length to width ratio of 2.8. Turner (1954) reported that *Pholas dactylus* in the USA attained a maximum length of 130 mm. The maximum size of *Barnea candida* reported by Pinn *et al*., (2005) of 38.2 mm and a ratio of 2.4 to 2.6, is much smaller than that found by Jefferies (1865; 56 mm and a ratio of 2.7), and Turner (1954; 68 mm and a ratio of 2.7 to 2.8) which may be due to substratum erosion at the site preventing piddocks reaching their potential lifespan and attaining full-size.

Duval (1977) proposed that it was as a result of the extensive borings of *Barnea candida* that facilitated the colonization of an area in the Thames Estuary by the introduced American piddock, *Petricolaria pholadiformis*. This suggests that *Barnea candida* is a more competitive colonizing species in clay environments than *Petricolaria pholadiformis* and it is possible that this species will appear first on cleared substrates. No other information on species interactions was found, although Pinn *et al*., (2005) noted that burrow morphology is altered (stunted, elongated, J-shaped or highly convoluted) in high density populations to avoid interconnecting with burrows of other individuals, suggesting that piddocks can detect the activities of local individuals (Pinn *et al*., 2005).

Richter & Sarnthein (1976) looked at the re-colonization of different sediments by various molluscs on suspended platforms in Kiel Bay, Germany. The platforms were suspended at 11, 15 and 19 m water depth, each containing three round containers filled with clay, sand, or gravel. Substratum type was found to be the most important factor for the piddock *Barnea candida*, although for all other species it was depth. This highlights the significance of the availability of a suitable substratum to the recovery of piddock species and suggests that larvae have some mechanisms for selection of suitable substratum. Richter & Sarnthein (1976) found that within the two year study period the piddocks grew to represent up to 98% of molluscan fauna on clay platforms. Piddock species have also shown very high growth rates of up to 54 mm in 30 months in the laboratory (Arntz & Rumohr, 1973). However, the process of colonization on clay at 15 and 19 m was found to be highly discontinuous, as reflected by the repeated growth and decrease of specimen numbers.

Although rare in the Romanian Black Sea, Micu (2007) reported the first observations of *Pholas dactylus* in 34 years at three locations illustrating the recovery potential of this species and ability to colonize or recolonize suitable habitat. The vulnerability of piddocks to episodic events such as the deposition of sediments (Hebda, 2011) and storm damage of sediments (Micu, 2007) and the on-going chronic erosion of suitable sediments (Pinn *et al*., 2005) indicate that larval dispersal and recruitment of new juveniles from source populations is an effective recovery mechanism allowing persistence of piddocks in suitable habitats.

Resilience assessment. The key characterizing species *Ceramium virgatum*, was considered to have 'High' resilience (recovery within 2 years) based on settlement studies. The sedentary nature of adult piddocks and their vulnerability to episodic events and chronic erosion suggest that piddocks have evolved effective strategies of larval dispersal and juvenile recruitment with some selectivity for suitable habitats. As recovery depends on recolonization and subsequent growth to adult size, resilience is assessed as 'Medium' (2-10 years) for all levels of resistance.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: Medium A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

Little direct evidence was found to assess the effects of increased temperature on piddocks and the assessment is based on distribution records and evidence for spawning in response to temperature changes. The American piddock *Petricolaria pholadiformis* has a wide distribution and is found north as far as the Skaggerak, Kattegat and Limfjord (Jensen, 2010) and is also present in the Mediterranean, Gulf of Mexico and Caribbean (Huber & Gofas, 2015). *Pholas dactylus* occurs in the Mediterranean and the East Atlantic, from Norway to Cape Verde Islands (Micu, 2007). *Barnea candida* is distributed from Norway to the Mediterranean and West Africa (Gofas, 2015).

There is some evidence that temperature influences the timing of reproduction in *Pholas dactylus*, which usually spawns between July and August. Increased summer temperatures in 1982 induced spawning in July on the south coast of England (Knight, 1984). Spawning of the piddock *Petricolaria pholadiformis* is initiated by increasing water temperature (>18 °C) (Duval, 1963a), so elevated temperatures outside of usual seasons may disrupt normal spawning periods. The spawning of *B. candida* was also reported to be disrupted by changes in temperature. *Barnea candida* normally spawns in September when temperatures are dropping (El-Maghraby, 1955). However, a rise in temperature in late June of 1956, induced spawning in some specimens of *Barnea candida* (Duval, 1963b). Disruption from established spawning periods, caused by temperature changes, may be detrimental to the survival of recruits as other factors influencing their survival may not be optimal, and some mortality may result. Established populations may otherwise remain unaffected by elevated temperatures.

Lüning (1990) reported that *Ceramium virgatum* (as *C. rubrum*) survived temperatures from 0 to 25 °C with optimal growth at about 15 °C. The species is therefore likely to be tolerant of higher temperatures than it experiences in the seas around Britain and Ireland. *Ulva intestinalis* is considered to be tolerant of elevated temperatures. It is characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days, whilst (Vadas *et al*., 1976) observed *Ulva intestinalis* to significantly increase in abundance near a heated effluent outfall.

Sensitivity assessment. The global distribution of the piddock species, *Petricolaria pholadiformis*, *Pholas dactylus* and *Barnea candida*, suggest that these species can tolerate warmer waters than currently experienced in the UK and may therefore be tolerant of a chronic increase in temperature. Short-term acute increases may, (depending on timing) interfere with spawning cues which appear to be temperature driven. The effects will depend on seasonality of occurrence and the species affected. Adult populations may be unaffected and, in such long-lived species, an unfavourable recruitment may be compensated for in a following year. Resistance to an acute change in temperature is therefore assessed as ‘High’ and recovery as ‘High’ (within two years) and the biotope is considered ‘Not Sensitive’. For all characterizing species it should be noted that the timing of acute changes may lead to greater impacts, temperature increases in the warmest months may exceed thermal tolerances whilst changes in colder periods may stress individuals acclimated to the lower temperatures.

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

Little empirical evidence was found to assess the effects of decreased temperature on piddocks and the assessment is based on distribution records and evidence for spawning in response to temperature changes.

The American piddock *Petricolaria pholadiformis* has a wide distribution and is found north as far as the Skaggerak, Kattegat and Limfjord (Jensen, 2010) (Huber & Gofas, 2015). *Pholas dactylus* occurs in the Mediterranean and the East Atlantic, from Norway to Cape Verde Islands (Micu, 2007). *Barnea candida* is distributed from Norway to the Mediterranean and West Africa (Gofas, 2015).

Temperature changes have been observed to initiate spawning by *Pholas dactylus*, which usually spawns between July and August. Increased summer temperatures in 1982 induced spawning in July on the south coast of England (Knight, 1984). Spawning of *Petricolaria pholadiformis* is initiated by increasing water temperature (>18 °C) (Duval, 1963a), so decreased temperatures may disrupt normal spawning periods where this coincides with the reproductive season. The spawning of *Barnea candida* was also reported to be disrupted by changes in temperature. *Barnea candida* normally spawns in September when temperatures are dropping (El-Maghraby, 1955). Disruption from established spawning periods, caused by decreased temperatures may be detrimental to the survival of recruits as other factors influencing their survival may not be optimal, and some mortality may result. Established populations may otherwise remain unaffected by decreased temperatures.

Lüning (1990) reported that *Ceramium virgatum* (as *Ceramium rubrum*) survived temperatures from 0 to 25 °C with optimal growth at about 15 °C. The species is therefore likely to be tolerant of lower temperatures than it experiences in the seas around Britain and Ireland. Sub-optimal temperatures may delay or slow reproduction.

Sensitivity assessment. Based on the wide range of temperature tolerance of *Ceramium virgatum*, it is concluded that the acute and chronic changes described by the benchmark would have limited effect. The global distribution of the piddock species also suggest that these species can tolerate cooler waters than currently experienced in the UK and may therefore be tolerant of a chronic decrease in temperature at the benchmark level. Decreased temperatures may, depending on timing, interfere with spawning cues which appear to be temperature driven. The effects will depend on seasonality of occurrence and the species affected. Adult populations may be unaffected and, in such long-lived species, an unfavourable recruitment may be compensated for in a following year. Based on the characterizing species, resistance to an acute and chronic decrease in temperature at the pressure benchmark is therefore assessed as 'High' and recovery as 'High' (within two years) and the biotope is considered 'Not Sensitive'.

Salinity increase (local)	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence for the range of physiological tolerances to salinity changes was found for piddocks. There is, therefore, no direct or indirect evidence for sensitivity to an increase in salinity.

Sensitivity assessment. No evidence for the range of physiological tolerances to salinity changes was found for piddocks and sensitivity to this pressure is not assessed based on 'No evidence'.

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

The biotope has only been recorded from conditions of full salinity (Connor *et al*., 2004). However, intertidal biotopes will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity. No direct empirical evidence was found to assess this pressure and the assessment is based on the reported distribution of characterizing species. *Barnea candida* is reported to extend into estuarine environments in salinities down to 20 psu (Fish & Fish, 1996). *Petricolaria pholadiformis* is particularly common off the Essex and Thames estuary, e.g. the River Medway (Bamber, 1985) suggesting tolerance of brackish waters. Zenetos *et al*. (2009) suggest that at all sites where *Petricolaria pholadiformis* has been found there is some freshwater inflow into the sea. According to the literature, the species in its native range inhabits environments with salinities between 29 and 35ppt, while in the Baltic Sea it is reported from salinities 10-30 psu (Gollasch & Mecke, 1996, cited from Zenetos *et al*. 2009). According to Castagna & Chanley (1973, cited from Zenetos *et al*. 2009) the lower salinity tolerance of *Petricolaria pholadiformis* is 7.5-10 psu. It thus appears that reduced salinity facilitates its establishment(Zenetos *et al*., 2009). No information was found for the salinity tolerance of *Pholas dactylus*.

The characterizing species *Ceramium virgatum* occurs over a very wide range of salinities. The species penetrates almost to the innermost part of Hardanger Fjord in Norway where it experiences very low salinity values and large salinity fluctuations due to the influence of snowmelt in spring (Jorde & Klavestad, 1963).

Sensitivity assessment. Based on reported distributions of *Ceramium* sp. and piddocks it is considered that the benchmark decrease in salinity (from full to variable) may result in reduced abundances of piddocks in biotopes that were previously fully marine and some change in species composition. In areas experiencing prolonged decreases in salinity, the ratio of *Petricolaria pholadiformis* to other species may change as a result of its greater tolerance to reduced salinities, but this would not lead to re-classification of biotope type. Resistance is therefore assessed as 'High' and resilience as 'High' and this biotope is therefore considered to be 'Not Sensitive'.

Water flow (tidal current) changes (local)	High Q: Medium A: Low C: NR	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

Established adult piddocks are, to a large extent, protected from direct effects of increased water flow, owing to their environmental position within the substratum. Increases or decreases in flow rates may affect suspension feeding by altering the delivery of suspended particles or the efficiency of filter feeding. However, no evidence was found to inform the sensitivity assessment although other biotopes characterized by piddocks (IR.MIR.KR.Ldig.Pid and CR.MCR.SfR.Pid) have been found in areas where tidal flows vary between 0.5 -1.5 m/s (Connor *et al*., 2004), suggesting that changes in flow rates within this range will not negatively impact piddocks. Adult piddocks may become exposed should physical erosion occur at a greater rate than burrowing, and lost from the substratum. At higher densities bioerosion by piddocks may destabilise the substratum increasing vulnerability to erosion. Increased scour, as a consequence of increased water flow could also inhibit settlement of juveniles and seaweed spores. The fronds of adults and germlings may also be damaged. Where the algal mat is dense some mitigation of water flow through friction and protection of the surface may occur although this effect will be lower than in biotopes characterized by robust species such as bivalves and fucoids and kelps.

The most damaging effect of increased flow rate would be the erosion of the peat substratum as this could eventually lead to loss of the habitat. Increased erosion would lead to the loss of habitat and removal of piddocks and the algal mat. No evidence was found to assess the water velocities at which erosion of peat occurs. Some erosion will occur naturally and storm events and wave action may be more significant in loss and damage of peats that surface water flow. Periodically peats are removed in storms to expose preserved submerged prehistoric landscapes around the UK.

Sensitivity assessment. No direct evidence was found to assess this pressure at the benchmark. Based on the exposure of piddocks in other biotopes to water flows between 0.5 and 1.5 m/s, the piddocks and algal mat are considered to be not sensitive to changes within this range as long as these do not lead to increased erosion of the substratum. Resistance is therefore assessed as 'High' and resilience as 'High' (based on no impact to recover from).

Emergence regime changes	Medium Q: Low A: NR C: NR	Medium Q: Medium A: Low C: Medium	Medium Q: Medium A: Low C: NR

Adult piddocks and the algae that characterize this biotope have no mobility and cannot, therefore, migrate up or down the shore to adapt to changes in emergence. Within the peat substratum, adult piddocks will be afforded some protection from desiccation and temperature increases following increased emergence by their burrows, which will retain some moisture. The shells of piddocks do not completely enclose the animals, however , and, therefore, cannot be closed to prevent water loss. The tolerance of piddocks to increased and decreased emergence varies between species. *Pholas dactylus* inhabits the shallow sub-tidal and lower shore and *Barnea candida* and *Petricolaria pholadiformis* live slightly higher up the shore than *Pholas dactylus* (Duval, 1977) . During extended periods of exposure, *Pholas dactylus* squirt some water from their inhalant siphon and extend their gaping siphons into the air (Knight, 1984). This may result in increased detection and predation by birds. Changes in emergence may, therefore, alter species abundances and ratios although the biotope will remain recognisable as a piddock biotope. The algal mat covering the substratum, predominantly of the red seaweed *Ceramium virgatum*, may be more intolerant of an increase in desiccation. *Ceramium virgatum* occurs profusely in rockpools, on the lower shore and in the subtidal but not on the open shore away from damp places suggesting that it is intolerant of desiccation. As a consequence of an increase in emergence, the algal cover may become diminished.

A decrease in emergence will reduce exposure to desiccation and extremes of temperature and allow the resident *Pholas dactylus*, *Barnea candida*, and *Petricolaria pholadiformis* to feed for longer periods and hence grow faster. No information was found on factors controlling the lower limit of piddock populations and it is possible, for example, that predation (predominantly siphon nipping by gobies, and other species, Micu, 2007) may increase at the lower edge of the biotope. Competition for space with species better adapted to the changed conditions may also alter habitat suitability for this biotope.

Sensitivity assessment. The biotope occurs in the eulittoral zone, where it experiences regular immersion and emersion. Species present are therefore tolerant of periods of emergence to some extent, however, changes in emergence regime may alter habitat suitability and increase levels of predation and competition. Based on these considerations, resistance to changes in emergence is assessed as 'Medium' as changes may alter the upper or lower margins of the biotope. Resilience is assessed as 'Medium' for piddocks so that sensitivity is assessed as 'Medium'.

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

No direct evidence was found to assess sensitivity to this pressure. The biotope typically occurs in moderately wave exposed locations. The piddocks are unlikely to be directly affected by changes in wave exposure, owing to their environmental position within the peat substratum, which protects them. On clay substrates, it is possible however, that wave action actively erodes the substratum at a faster rate than the piddocks leaving them vulnerable and exposed. At higher densities bioerosion by piddocks may destabilise the substratum increasing vulnerability to erosion. *Ceramium virgatum* occurs in extremely wave sheltered conditions (for instance, it is characteristic in a number of sheltered or very sheltered biotopes (Connor *et al.*, 2004) and is recorded in some of the most sheltered parts of Hardangerfjord in Norway (Jorde & Klavestad, 1963). Strong wave action is likely to cause some damage to fronds resulting in reduced photosynthesis and compromised growth. Furthermore, individuals may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action (Hiscock, 1983).

An increase in wave height may facilitate upward exapansion of biotope margins where wave splash ameliorates effects of emergence and dessication but this is not considered significant at the pressure benchmark.

Potentially the most damaging effect of increased wave heights would be the erosion of the peat substratum as this could eventually lead to loss of the habitat. Increased erosion would lead to the loss of habitat and removal of piddocks and the algal mat. No evidence was found to link significant wave height to erosion. Some erosion will occur naturally and storm events may be more significant in loss and damage of peats than changes in wave height at the pressure benchmark.

Sensitivity assessment. No direct evidence was found to assess this pressure at the benchmark. Based on the occurrence of this biotope in moderately wave exposed habitats the piddocks and algal mat are considered to have 'High' resistance to changes at the pressure benchmark where these do not lead to increased erosion of the substratum. Resilience is therefore assessed as 'High' and the biotope is considered to be 'Not sensitive', at the pressure benchmark.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	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** but evidence is presented where available.

Hydrocarbon & PAH contamination	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** but evidence is presented where available.

Synthetic compound contamination	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** but evidence is presented where available.

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

Specific information concerning oxygen consumption and reduced oxygen tolerances were not found for important characterizing species within the biotope. Cole *et al.* (1999) suggested possible adverse effects on marine species below 4 mg O_2/l and probable adverse effects below 2mg O_2/l . Duval (1963a) observed that conditions within the borings of *Petricolaria pholadiformis* were anaerobic and lined with a loose blue/black sludge, suggesting that the species may be relatively tolerant to conditions of reduced oxygen. However, insufficient information has been recorded. As this biotope occurs in the intertidal, emergence will mitigate the effects of hypoxic surface waters as will the exposure to wave action and water flows and this pressure is considered to be 'Not relevant'.

Nutrient enrichment	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The benchmark is set at compliance with WFD criteria for good status, based on nitrogen concentration (UKTAG, 2014). No evidence was found to assess the sensitivity of piddocks to this pressure. Hily *et al*. (1992) found that, in conditions of high nutrients, *Ceramium virgatum* (as *Ceramium rubrum*) and *Ulva* sp. dominated substrata in the Bay of Brest, France. *Ceramium* spp. are also mentioned by Holt *et al*. (1995) as likely to smother other species of macroalgae in nutrient enriched waters. Fletcher (1996) quoted *Ceramium virgatum* (as *Ceramium rubrum*) to be associated with nutrient enriched waters. It therefore seems that algal stands of *Ceramium virgatum* are likely to benefit from elevated levels of nutrients. Furthermore, nutrient enrichment that enhances productivity of phytoplankton may indirectly benefit the suspension feeding piddocks by increasing food supply.

Sensitivity assessment. The pressure benchmark is set at a level that is relatively protective and based on the evidence and considerations outlined above the biological assemblage is considered to be 'Not sensitive' at the pressure benchmark. Resistance and resilience are therefore assessed as 'High'.

Organic enrichment	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence was found to assess this pressure.

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.

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

This biotope is characterized by the fossilised peat substratum which supports populations of burrowing piddocks. A change to a sedimentary, rock or artifical substratum result in the loss of piddocks significantly altering the character of the biotope. The biotope is therefore considered to have 'No' resistance to this pressure, recovery of the biological assemblage (following habitat restoration) is considered to be 'Medium' (2-10 years) but see caveats in the recovery notes. The biotope is dependent on the presence of fossilised peat, when lost restoration would not be feasible and recovery is therefore categorised as 'Very low'. Sensitivity is therefore assessed as 'High', based on the lack of recovery on peat substratum. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

This biotope is characterized by the fossilised peat substratum which supports populations of burrowing piddocks. A change to a sedimentary substratum would result in the loss of piddocks significantly altering the character of the biotope. The biotope is therefore considered to have 'No' resistance to this pressure, recovery of the biological assemblage (following habitat restoration) is considered to be 'Medium' (2-10 years) but see caveats in the recovery notes. The biotope is dependent on the presence of fossilised peat, when lost restoration would not be feasible and recovery is therefore categorised as 'Very low'. Sensitivity is therefore assessed as 'High', based on the lack of recovery on peat substratum. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

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

The removal of substratum to 30cm depth will remove the entire surface algal mat, associated biological assemblage and the piddocks, in the impact footprint. Resistance is therefore assessed as ‘None’, recovery of the biological assemblage (following habitat restoration) is considered to be 'Medium' (2-10 years) but see caveats in the recovery notes. The biotope is dependent on the presence of fossilised peat, when lost restoration would not be feasible and recovery is therefore categorised as 'Very low'. Sensitivity is therefore assessed as 'High', based on the lack of recovery on peat substratum. Although no specific evidence is described confidence in this assessment is ‘High’, due to the incontrovertible nature of this pressure.

Abrasion/disturbance of the surface of the substratum or seabed	Medium Q: Low A: NR C: NR	Very Low Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR

Within this biotope the dense algal mat of red and green seaweed could be damaged and removed by surface abrasion. Some species protruding from the surface, e.g. *Lanice conchilega*, *Sabella pavonina* may also be removed. Although the piddocks are afforded some protection from surface abrasion by living in their burrows, the peat is soft which leaves many individuals, especially those near the surface of the clay, vulnerable to damage and death through exposure, sediment damage and compaction. Micu (2007) for example observed that after storms in the Romanian Black Sea, the round goby, *Neogobius melanostomus*, removed clay from damaged or exposed burrows to be able to remove and eat piddocks.

The most significant impact from abrasion may be the habitat effects of removal and damage to the peat substratum. Natural erosion processes are, however, likely to be on-going within this habitat type. Where abundant the boring activities of piddocks contribute significantly to bioerosion, which can make the substratum habitat more unstable and can result in increased rates of coastal erosion (Evans 1968, Trudgill 1983, Trudgill & Crabtree, 1987). Pinn *et al*. (2005) estimated that over the lifespan of a piddock (12 years), up to 41% of the shore could be eroded to a depth of 8.5 mm. The burrowing activities of piddocks may therefore weaken the substratum increasing the potential damage from substratum abrasion.

Sensitivity assessment. Surface abrasion may remove the algal mat and surface infauna and result in the loss of some piddocks and damge to habitat. Resistance is therefore assessed as 'Low' for the algal mat and 'Medium' for piddocks and substratum. The algal mat and surface infauan are predicted to remover within 2 years, so that resilience is considered to be 'High' and sensitivity is 'Low'. As the substratum cannot recover, resilience is assessed as 'Very Low' and sensitivity of the overall biotope is considered to be 'Medium'.

Penetration or disturbance of the substratum subsurface	Low Q: Low A: NR C: NR	Very Low Q: Low A: NR C: NR	High Q: Low A: NR C: NR

Penetration and disturbance below the surface of the substratum will damage and remove the dense algal mat and surface fauna and could damage and expose piddocks. Piddocks in damaged burrows or those that are removed from the substratum are unlikely to be able to rebury and will be predated by fish and other mobile species (Micu, 2007).

The most significant impact may be the damage to, and removal of, the peat substratum. Where abundant the boring activities of piddocks can make the substratum habitat more unstable and can exacerbate erosion (Evans 1968, Trudgill 1983,Trudgill & Crabtree, 1987). Pinn *et al.* (2005) estimated that over the lifespan of a piddock (12 years), up to 41% of the shore could be eroded to a depth of 8.5 mm. The piddock burrowing activities may therefore weaken the substratum so that it is more vulnerable to damage and erosion.

Sensitivity assessment. Sub-surface penetration and disturbance will remove and damage the algal mat and surface infauna and result in the loss of piddocks and damage to the habitat. Resistance is therefore assessed as 'Low' for the algal mat piddocks and substratum. The algal mat and surface infauana are predicted to remover relatively rapidly and the piddocks within 2-10 years so that resilience of the biological assemblage is considered to be 'Medium' and sensitivity is 'Medium'. As the substratum cannot recover, resilience is assessed as 'Very Low' and sensitivity of the overall biotope is considered to be 'High'.

Changes in suspended solids (water clarity)	High Q: High A: Low C: Medium	High Q: High A: High C: High	Not sensitive Q: High A: Low C: Medium

No direct evidence was found to assess this pressure. Increased suspended particles will decrease light penetration, may enhance food supply (where these are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). Very high levels of silt may clog respiratory and feeding organs of some suspension feeders. Increased levels of particles may increase scour and deposition in the biotope depending on local hydrodynamic conditions. The piddocks are protected from scour within burrows and increased organic particles will provide a food subsidy. *Pholas dactylus* occurs in habitats such as soft chalks where turbidity may be high and is therefore unlikely to be affected by an increase in suspended sediments at the pressure benchmark. Piddocks, in common with other suspension feeding bivalves, have efficient mechanisms to remove inorganic particles via pseudofaeces. Experimental work on *Pholas dactylus* showed that large particles can either be rejected immediately in the pseudofaeces or passed very quickly through the gut (Knight, 1984). Similarly *Petricolaria pholadiformis* is able to tolerate high-levels of suspended solids through the production of pseudofaeces (Purchon, 1955). Increased suspended sediments may impose sub-lethal energetic costs on piddocks by reducing feeding efficiency and requiring the production of pseudofaeces with impacts on growth and reproduction.

Macroalgae within the biotope may be sensitive to decreased light penetration, however Hily *et al*. (1992) found that, in conditions of high turbidity, the characterizing species *Ceramium virgatum* (as *Ceramium rubrum*) (and *Ulva* sp.) dominated sediments in the Bay of Brest, France. It is most likely that *Ceramium virgatum* thrived because other species of algae could not. Whilst the field observations in the Bay of Brest suggested that an increase in abundance of *Ceramium virgatum* might be expected in conditions of increased turbidity, populations where light becomes limiting will be adversely affected. However, in shallow depths and the intertidal , photosynthesis can occur during low tides (as long as sediments are not deposited) and *Ceramium virgatum* may benefit from increased turbidity through decreased competition.

A significant decrease in suspended organic particles may reduce food input to the biotope resulting in reduced growth and fecundity of piddocks. However, local primary productivity may be enhanced where suspended sediments decrease, increasing food supply. Decreased suspended sediment may increase macroalgal competition enhancing diversity but is considered unlikely to significantly change the character of the biotope.

Sensitivity assessment. No direct evidence was found to assess sensitivity to this pressure however, based on the tolerance of *Ceramium* sp. to increased turbidity and the occurrence of *Pholas dactylus* in turbid areas and evidence for the production of pseudofaeces by piddocks, resistance is assessed as 'High' and resilience as High (no impact to recover from). The biotope is therefore considered to be 'Not sensitive'.

Smothering and siltation rate changes (light)	Low Q: Low A: NR C: NR	Medium Q: Low A: NR C: NR	Medium Q: Low A: Low C: Low

The burrowing mechanisms of the piddocks *Pholas dactylus* and *Barnea candida* and other Pholads, mean that the burrows have a narrow entrance excavated by the juvenile. As the individual grows and excavates deeper the burrow widens resulting in a conical burrow from which the adult cannot emerge. *Petricolaria pholadiformis* excavates a cylindrical burrow (Ansell, 1970) and hence may be able to relocate in sandy sediments, however although burrowing mechanisms have been studied, however no evidence was found to suggest this species can re-emerge through sediments and re-bury. Piddocks cannot therefore emerge from layers of deposited silt as other more mobile bivalves can.

No examples of direct empirical evidence or experiments on mortality rates have been found. Sometimes the substratum in which piddocks reside is covered by a thin layer of loose sandy material, through which the piddocks maintain contact with the surface via their siphons. It is likely that the piddocks would be able to extend their siphons through loose material, particularly where tidal movements shift the sand around. *Pholas dactylus* have been found living under layers of sand in Aberystwyth, Wales, (Knight, 1984) and in Eastbourne, with their siphons protruding at the surface (Pinn *et al*., 2008). *Barnea candida* has also been found to survive being covered by shallow layers of sand in Merseyside (Wallace & Wallace, 1983). Wallace & Wallace (1983) were unsure as to how long the *Barnea candida* could survive smothering but noted that, on the coast of the Wirral, the piddocks have survived smothering after periods of rough weather. Where smothering is constant, survival can be more difficult. The redistribution of loose material following storms off Whitstable Street, in the Thames Estuary, is thought to be responsible for the suffocation of many *Petricolaria pholadiformis* and it is possible that this species may be the most intolerant of the three piddock species associated with this biotope. However, it was not known how deep the layer of 'loose material' was, nor how long it lasted for or what type of material it was made up of.

Indirect indications for the impacts of siltation are provided by studies of Witt *et al*., (2004) on the impacts of harbour dredge disposal. *Petricola pholadiformis* was absent from the disposal area, and Witt *et al*., (2004) cite reports by Essink (1996, not seen) that smothering of *Petricola pholadiformis* from siltation could lead to mortality within a few hours. Hebda (2011) also identified that sedimentation may be one of the key threats to *Barnea truncata* populations. At Agigea (Micu, 2007) reported that smothering of clay beds by sand and finer sediments had removed populations of *Pholas dactylus*. In this area sand banks up to 1m thick frequently shift position driven by storm events and currents (Micu, 2007). Similar smothering was described in the case of *Barnea candida* populations boring into clay beds (Gomoiu & Muller 1962, cited from Micu, 2007).

Species comprising, and living within the dense algal mat are likely to be intolerant of smothering. Sporelings would certainly be adversely affected as Vadas *et al*. (1992) stated that algal spores and propagules are adversely affected by a layer of sediment, which can exclude up to 98% of light.

Sensitivity assessment. As piddocks are essentially sedentary and as siphons are relatively short, siltation from fine sediments rather than sands, even at low levels for short periods could be lethal. Resistance to siltation is assessed as ‘Low’ for piddocks and the algal mat although effects would be mitigated where water currents and wave exposure rapidly removed the overburden and this will depend on shore height and local hydrodynamic conditions. Resilience is assessed as ‘Medium’ (2-10 years) for piddocks and sensitivity is therefore assessed as ‘Medium’.

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

The burrowing mechanisms of the piddocks *Pholas dactylus* and *Barnea candida* and other Pholads, mean that the burrows have a narrow entrance excavated by the juvenile. As the individual grows and excavates deeper the burrow widens resulting in a conical burrow from which the adult cannot emerge. *Petricola pholadiformis* excavates a cylindrical burrow (Ansell, 1970) and hence may be able to relocate in sandy sediments, however although burrowing mechanisms have been studied, however no evidence was found to suggest this species can re-emerge through sediments and re-bury. Piddocks cannot therefore emerge from layers of deposited silt as other more mobile bivalves can.

No examples of direct empirical evidence or experiments on mortality rates in response to siltation have been found for piddocks. Indirect indications for the impacts of siltation are provided by studies of Witt *et al*., (2004) on the impacts of harbour dredge disposal. *Petricola pholadiformis* was absent from the disposal area, and Witt *et al*., (2004) cite reports by Essink (1996, not seen) that smothering of *Petricola pholadiformis* from siltation could lead to mortality within a few hours. Hebda (2011) also identified that sedimentation may be one of the key threats to *Barnea truncata* populations. At Agigea (Micu, 2007) reported that smothering of clay beds by sand and finer sediments had removed populations of *Pholas dactylus*. In this area sand banks up to 1m thick frequently shift position driven by storm events and currents (Micu, 2007). Similar smothering was described in the case of *Barnea candida* populations boring into clay beds (Gomoiu & Muller 1962, cited from Micu, 2007).

Species comprising, and living within the dense algal mat are likely to be intolerant of smothering.

Sensitivity assessment.Siltation at the pressure benchmark is considered to remove most or all of the piddocks and the surface algae and fauna. Resistance to siltation is therefore assessed as ‘None' although effects could be mitigated where water currents and wave exposure rapidly removed the overburden and this will depend on shore height and local hydrodynamic conditions. Resilience is assessed as ‘Medium’ (2-10 years) for piddocks and sensitivity is therefore assessed as ‘Medium’.

Litter	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

Not assessed.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

No evidence.

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

Not relevant.

Introduction of light or shading	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Pholaas dactylus can perceive and react to light (Hecht, 1928) however there is no evidence that this pressure would impact the biotope.

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

Not relevant.

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

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

Visual disturbance	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: NR C: NR

Pholas dactylus reacts quickly to changes in light intensity, after a couple of seconds, by withdrawing its siphon (Knight, 1984). This reaction is ultimately an adaptation to reduce the risk of predation by, for example, approaching birds (Knight, 1984). However, its visual acuity is probably very limited and it is unlikely to be sensitive to visual disturbance. Birds are highly intolerant of visual presence and are likely to be scared away by increased human activity, therefore reducing the predation pressure on piddocks. Therefore, visual disturbance may be of indirect benefit to piddock populations and the biotope is considered to be 'Not sensitive'. Resistance and resilience are therefore assessed as 'High' by default.

Biological Pressures

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

The species characterizing this biotop are not farmed or translocated and therefore this pressure is 'Not relevant' to this biotope.

Introduction or spread of invasive non-indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The surface of the peat is friable and subject to on-going erosion and therefore this habitat does not support large, long-lived, attached species. The algal mat characterizing this biotope consists of small, ephemeral species, replacement of these species by invasive non-indigenous algal species could occur and alter the character of the biotope. However, no evidence was found in the literature to suggest that invasive non-indigenous species are present in UK marine and coastal peat habitats.

The presence of The American piddock, *Petricolaria pholadiformis* is a non-native, boring piddock that was unintentionally introduced from America with the American oyster, *Crassostrea virginica*, not later than 1890 (Naylor, 1957). Rosenthal (1980) suggested that from the British Isles, the species has colonized several northern European countries by means of its pelagic larva and may also spread via driftwood, although it usually bores into clay, peat or soft rock shores. In Belgium and The Netherlands *Petricolaria pholadiformis* almost completely displaced the native piddock, *Barnea candida* (ICES, 1972). However, this has not been observed elsewhere, and later studies have found that *Barnea candida* is now more common than *Petricolaria pholadiformis* in Belgium (Wouters, 1993) and there is no documentary evidence to suggest that *Barnea candida* has been displaced in the British Isles (J. Light & I. Kileen pers. comm. to Eno *et al*., 1997). *Petricolaria pholadiformis* is considered unlikely to displace *Pholas dactylus* which is more likely to occur subtidally. Should *Petricolaria pholadiformis* is be present in this biotope it is not considered to alter the character or ecological function of the biotope.

Although not currently established in UK waters, the whelk *Rapana venosa*, may spread to habitats. This species has been observed predating on *Pholas dactylus* in the Romanian Black Sea by Micu (2007).

Sensitivity assessment. Based on the lack of records of invasive non-indigenous species in this biotope, and the unsuitability of the habitat for algae and other attached epifauna this biotope is considered to have ‘High’ resistance to this pressure and, by default ‘High’ resilience, this biotope is therefore considered to be ‘Not sensitive’. This assessment may need revising in light of future invasions, e.g. the introduction of the whelk *Rapana venosa*.

Introduction of microbial pathogens	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No evidence was found for the impact of microbial pathogens on characterizing species, based on the lack of evidence for outbreaks of disease or significant mortality this biotope was considered to have 'High' resistance to this pressure and 'High' resilience (by default), and is therefore assessed as 'Not sensitive'.

Removal of target species	Low Q: Low A: NR C: NR	Very Low Q: Low A: NR C: NR	High Q: Low A: Low C: Low

Piddocks may be removed as bait and across Europe they have traditionally been harvested for food, however high levels of habitat damage are associated with the removal of boring molluscs (Fanelli *et al*., 1994) and this practice has largely been banned. The most sensitive component of this biotope to targeted harvesting is the peat substratum which may be damaged and removed if piddocks were excavated from their burrows, this effect is considered through the physical damage pressures, abrasion and penetration and sub-surface damage.

Sensitivity assessment. Removal of piddocks will result in loss of targeted individuals and damage to the habitat. Resistance is assessed as ‘Low’ as piddocks are sedentary and burrow openings are readily detected. Piddocks are predicted to recover within 2-10 years so that resilience is considered to ‘Medium’ and sensitivity is ‘Medium’. Resistance of the habitat to removal of substratum to extract sediments is assessed as 'Low' and resilience as 'Very Low' based on no recovery, so that sensitivity is 'High'. The more sensitive habitat assessment and associated confidence is presented in the table.

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

Surface algal mats and infauna may be removed or damaged by activities targeting other species. These direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures. Removal of the algal mat may alter the character of the biotope but it is unlikely that targeted harvesting of other species would remove all of the mat or unintentionally remove piddocks. Resistance of surface fauna and flora is assessed as 'Medium' and resilience as 'High' so that sensitivity is assessed as 'Low' (based on the algal mat).

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