Melinna palmata with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud

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Melinna palmata **with** *Magelona spp.* **and** *Thyasira spp.* **in infralittoral sandy mud**
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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)
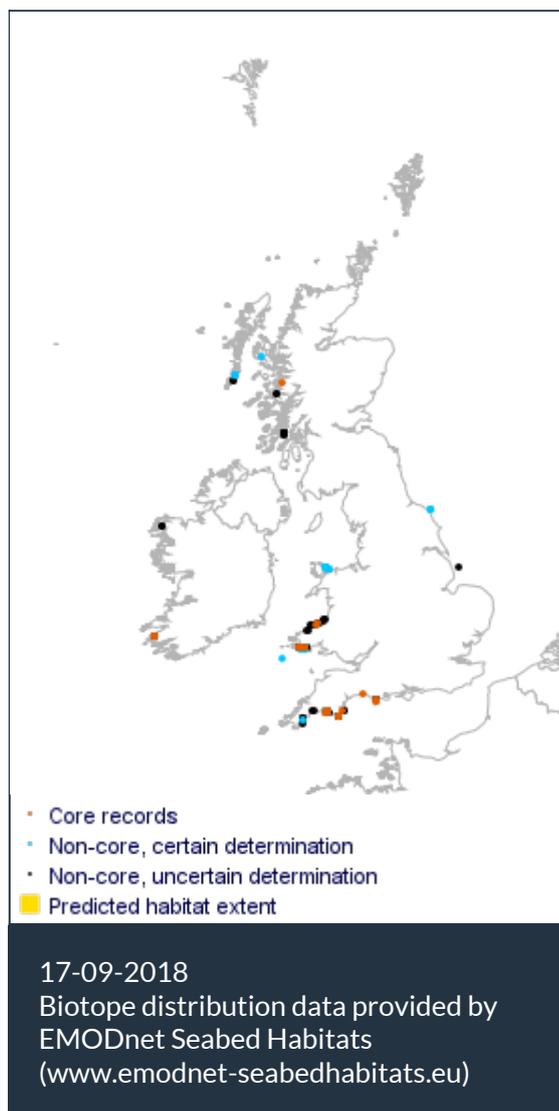
Researched by   Eliane De-Bastos   **Refereed by**   This information is not refereed.

Summary

≡ UK and Ireland classification

EUNIS 2008	A5.334	*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud
JNCC 2015	SS.SMu.ISaMu.MelMagThy	*Melinna palmata* with *Magelona* spp. and *Thyasira* spp. in infralittoral sandy mud
JNCC 2004	SS.SMu.ISaMu.MelMagThy	*Melinna palmata* with *Magelona spp.* and *Thyasira spp.* in infralittoral sandy mud
1997 Biotope		

🏷 Description

In infralittoral cohesive sandy mud, in sheltered marine inlets, and occasionally variable salinity environments, dense populations of the polychaete *Melinna palmata* may occur, often with high numbers of *Magelona* spp. and the bivalve *Thyasira flexuosa*. Other important taxa may include

Chaetozone gibber, Nephtys hombergii, Galathowenia oculata, Euclymene oerstedi (syn. *Euclymene oerstedii*), *Ampelisca tenuicornis, Ampharete lindstroemi, Abra alba, and Phoronis* sp. In addition the polychaete *Aphelochaeta* spp. and the gastropod *Turritella communis* may be common or abundant in some areas. At the sediment surface visible taxa may include occasional *Virgularia mirabilis*, and mobile epifauna such as *Pagurus bernhardus*. This biotope is characteristic in many southern UK marine inlets and in some areas e.g. Plymouth Sound during high levels of recruitment when *Melinna palmata* often occurs in abundances between 500 to 1000 per m^2 moderate numbers of the species often 'overspill' into adjacent biotopes (Allen *et al.*, 2001) (Information taken from Connor *et al.*, 2004).

↓ Depth range

5-10 m, 10-20 m

🏛 Additional information

-

✔ Listed By

- none -

❧ Further information sources

Search on:

G g G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMu.ISaMu.KurAbr is a shallow sublittoral biotope occurring in very sheltered conditions with very weak tidal streams (Connor *et al.*, 2004). This hydrographic regime allows for the occurrence of cohesive sandy muds, sometimes with a small quantity of shell, that support populations of the small bivalves *Kurtiella bidentata* (syn. *Mysella bidentata*) and *Abra* spp. (typically *Abra alba* and *Abra nitida*) that identify this biotope. Other characteristic taxa may include polychaetes, other bivalves, and tube building amphipods. This biotope is generally found in sheltered marine inlets or sea loughs such as Strangford Lough.

SS.SMu.ISaMu.MelMagThy is also a sublittoral biotope occurring in very sheltered conditions but with moderately strong tidal streams (Connor *et al.*, 2004). This hydrographic regime also allows for the development of a cohesive sandy mud substratum. Given that the biotope may often occur in sheltered marine inlets, variable salinity environments may occasionally develop. The biotope supports dense populations of the polychaete *Melinna palmata* and *Magelona* spp. and bivalve *Thyasira flexuosa*, which identify the biotope. Other important taxa may include polychaetes, amphipods, small bivalves and a number of epifaunal species. This biotope is characteristic in many southern UK marine inlets e.g. Plymouth Sound.

Both these biotopes are diverse and support a number of species that contribute to species richness and diversity but are not considered important characterizing, defining or structuring species and are not considered within the assessments. More information on these species can be found in other biotope assessments available on this website. Given the dense diversity of infaunal species it is likely that the communities contribute to the stability of the soft sediments where the biotopes occur, playing a key structural role in the biotopes. However, the biotopes are identified by the occurrence of *Kurtiella bidentata* and *Abra* spp., and *Melinna palmata* with *Magelona* spp. and *Thyasira* spp. respectively, so these species are considered important characterizing species and are the focus of this sensitivity assessment.

Resilience and recovery rates of habitat

Kurtiella bidentata is a very small commensal bivalve, up to 3 mm in length (Carter, 2008). The bivalve is often found in muddy sand or fine gravel, and associated to other species (e.g. brittlestar *Acrocnida brachiata* and other ophiurids) (Ockelmann & Muus, 1978; Carter, 2008). It is a viviparous species, with larvae retained in the gill pouch until an early veliger stage, which then live for some time in the sea, common in summer and autumn (Lebour, 1938). *Kurtiella bidentata* produce planktonic larvae during a prolonged spawning season (Larsen *et al.*, 2007) so are considered to have a high dispersal potential. Recruitment occurred during August-October and three year-classes were identified (O'Foighil *et al.*, 1984). It is not known at what age this species becomes sexually mature although in their first year, both males and hermaphrodites can be found (Marshall, 2005). *Kurtiella bidentata* (studied as *Mysella bidentata*) was reported to be fast growing and have a lifespan of 5-6 years in the North sea (Künitzer, 1989).

Abra spp. are opportunistic small bivalves, capable of exploiting newly disturbed substratum through larval recruitment, secondary settlement of post-metamorphosis juveniles, or redistribution of adults (Rees & Dare, 1993). *Abra alba* may grow up to 25 mm in length, and spawns at least twice a year over a protracted breeding period (Budd, 2007). Timing of spawning and settlement suggests that the larval planktonic phase lasts at least a month (Dauvin & Gentil,

1989 cited in Budd, 2007), allowing high potential dispersal. In addition to dispersal via the plankton, dispersal of post-settlement juveniles may occur via byssus drifting (Sigurdsson *et al.*, 1976) and probably bed load transport (Emerson & Grant, 1991). Fertilization is external and larvae are subject to very high mortality. At metamorphosis, the larvae settle out of the plankton and the bivalve spends its remaining life as a member of the benthos (Dame, 1996). Recruitment seems to vary between localities. In a population of *Abra alba* from the Irish Sea, animals reached maturity between June and September. In Kiel Bay, Baltic Sea a recruitment peak occurred in August, sometimes with a second peak between December and February (Rainer, 1985). Autumn settled individuals from the Bay of Morlaix, France, initially showed no significant growth; in contrast, veliger larvae that settled during the summer grew very rapidly, lived about one year and spawned only once (Dauvin & Gentil, 1989). Dauvin & Gentil (1989) observed three recruitment periods in response to trophic conditions following the *Amoco Cadiz* oil spill in the Bay of Morlaix, France. The additional recruitment period was considered to be an adaptive response over the normal pattern of twice yearly recruitment. Two peaks were noted in the Limfjord (Jensen, 1988). Warwick & George (1980) inferred that settlement in Swansea Bay, Wales, occurred over a period of months between July and November. *Abra nitida* is a small bivalve up to 2 cm in length and 1.2 cm in height, similar to *Abra alba*. *Abra nitida* recruitment tends to be episodic and may be negatively affected by the presence of predators and inhibited by high densities of adults (Josefson, 1982). *Abra nitida* also has a larval planktonic phase indicating a high dispersal potential. Usually this species occurs in dense aggregations that undergo subsequent decline and then recover through dense settlement (Josefson, 1982).

Melinna palmata is a polychaete worm from the family Ampharetidae. It has been recorded to live up to 5 years (Retière, 1979) but individuals typically have a shorter life expectancy of 22-28 months (Guillou & Hily, 1983). *Melinna* is a sessile, tubicolous species, living in a mucus lined tube covered with sediment particles that projects above the surface (Fauchald & Jumars, 1979). Spawning occurs between May and July but not until the worms are 2 years old (Rouse & Pleijel, 2001). This species may be found in very high densities, but numbers may vary due to recruitment and mortality. Within Galway Bay, Grehan (1991) found that sexual maturity was reached at two years and the species has a planktonic dispersal phase allowing colonization of disturbed patches. First colonization of this species was observed in May, eight months after dredging had ceased in the Harbour of Brest, France (Guillou & Hily, 1983). Initial cohorts had high growth rates and short-lifespans (22 months), the following cohorts were longer-lived but growth rates were lower indicating this species can change demographic strategy. Recovery of disturbed patches will occur through larval settlement and inward migration of juveniles and adults (Guillou & Hily, 1983).

Magelona spp. are small-medium sized polychaete worms up to 5-20 cm length free-living within sediments. *Magelona* lives for about 3 years and reaches maturity at 2 years. There is only one reproductive period, which occurs between May-October. The eggs released by the female are fertilized externally and develop into planktotrophic larvae that settle from June-November. The genus has a high dispersal potential and evidently forms dense communities with a relatively rapid growth rate (MES, 2010).

Little information was available for *Thyasira flexuosa*. The larval development of the congener *Thyasira equalis* is lecithotrophic and the pelagic stage is very short or suppressed (Tillin & Tyler-Walters, 2014). This agrees with the reproduction of other *Thyasira* sp., and in some cases (e.g. *Thyasira gouldi*) no pelagic stage occurs at all (Thorson, 1946, 1950). This means that larval dispersal is limited. Sparks-McConkey & Watling (2001) found that a population of *Thyasira flexuosa* in Penobscot Bay, Maine recovered rapidly (within 3.5 months) following trawler disturbance that resulted in a decrease in the population. Benthic reproduction allows

recolonization of nearby disturbed sediment and leads to rapid recovery where a large proportion of the population remains to repopulate the habitat.

Resilience assessment: Subtidal sedimentary habitats are more resilient than other habitats as they can be easily affected by natural disturbance of sediment. Recovery of habitats following a disturbance is dependent on physical, chemical and biological processes and can be a more rapid process than in other areas (Bishop *et al.*, 2006; cited in Fletcher *et al.*, 2011). However, recovery times after physical disturbance have been found to vary for different sediment types (Roberts *et al.*, 2010). Dernie *et al.* (2003) found that muddy sand habitats had the longest recovery times, compared to mud and clean sand habitats. Population recovery rates will be species specific. Removal of the characterizing species *Kurtiella bidentata*, *Abra* spp., *Melinna palmata*, *Magelona* spp. and *Thyasira* spp. would result in the biotopes being lost and/or reclassified. SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThy are likely to reach maturity rapidly because the key species are short lived and reach maturity rapidly. *Kurtiella bidentata* and *Magelona* have high dispersal potentials; *Abra* spp. are likely to recover rapidly although recruitment may be episodic. Where the habitat is suitable, recovery of *Melinna* and *Thyasira* spp. are expected to be high, based on recruitment from the local population. So where perturbation removes a portion of the population or even causes local extinction (resistance High, Medium or Low) resilience is likely to be **High** for as long as habitat is suitable and recruitment from neighbouring areas is possible. However, in areas of suitable habitat that are isolated, where total extinction of the population occurs (resistance None) recovery is likely to depend on favourable hydrodynamic conditions that will allow recruitment from farther away. Given the low energy environment where the biotopes occur and the low dispersal potential of some of the species in the biotopes, recruitment to recolonize impacted areas may take longer. However, once an area has been recolonized, restoration of the biomass of the characterizing species is likely to occur quickly and resilience is likely to be **Medium** (full recovery within 2-10 years).

NB: 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 recognizable 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	High	Low
	Q: Medium A: Medium C: High	Q: Low A: NR C: NR	Q: Low A: NR C: NR

The species are widely distributed. *Kurtiella bidentata* is widespread around the British Isles and its distribution ranges from Norway to west Africa and the Mediterranean (Carter, 2008). *Abra* spp. are also widespread around the British Isles, with *Abra alba* occurring from the Norwegian Sea and the Baltic, south to the Iberian Peninsula, into the Mediterranean and Black seas, and south along the coast of Africa to Senegal (Budd, 2007), and *Abra nitida* from Norway south to Mediterranean

and north-west Africa (Hayward & Ryland, 1995b). *Melinna palmata* spreads from northern Spain with scattered records in the Mediterranean, Morocco, Black Sea and Arabian Gulf (Hayward & Ryland, 1995b). *Magelona filiformis* and *Magelona mirabilis* are widespread on the coasts of Britain and Northern Ireland (Rayment, 2007b; Richards, 2007), with the latter also extending to north-west Europe to Mediterranean (Hayward & Ryland, 1995b). *Thyasira flexuosa* does not occur in the southernmost part of the North Sea but is distributed from Norway to the Azores, and extends into the Mediterranean (Tillin & Tyler-Walters, 2014). However, *Thyasira* populations in the British Isles are restricted to areas where the bottom waters remain cool all year round (Jackson, 2007).

No specific information concerning temperature tolerances of the biotopes and the characterizing species was found, but inferences may be made. For example, *Kurtiella bidentata* (studied as *Mysella bidentata*) was recorded in Kinsale Harbour at temperatures ranging from 7.7-18.8°C (O'Brien & Keegan, 2006), and Künitzer *(1989)* reported that the main factor affecting the growth rate of *Kurtiella bidentata* (studied as *Mysella bidentata*) was temperature.

Wilson (1981) investigated temperature tolerances of six bivalve species from Dublin Bay. The author concluded that species variations in tolerance to increased temperature varied seasonally and with distribution along tidal height. Lethal temperatures for all six bivalve species in the study varied greatly and were, in most cases, well above 20°C. The maximum sea surface temperatures around the British Isles rarely exceed 20°C (Hiscock, 1998).

Sensitivity assessment. The characterizing species of the biotopes are widely distributed and likely to occur both north and south of the British Isles, where typical surface water temperatures vary seasonally from 4-19°C (Huthnance, 2010). No information was found on the maximum temperature tolerated by the characterizing species. Elevated temperatures may affect growth of some of the characterizing species, but no mortality is expected. It is therefore likely that *Kurtiella bidentata*, *Abra* spp., *Melinna palmata*, *Magelona* spp. and *Thyasira* spp. are able to resist a long-term increase in temperature of 2°C. However, *Thyasira* spp. may suffer some mortality as a result of an acute increase in temperature so resistance is therefore assessed as **Medium** (loss <25%). Resilience is likely to be **High,** so the biotopes are considered to have **Low** sensitivity to an increase in temperature at the pressure benchmark level.

Temperature decrease (local)	Low	High	Low
	Q: Medium A: Medium C: High	Q: Low A: NR C: NR	Q: Low A: NR C: NR

There is no information on the response of the biotopes to a decrease in temperature, but species are widely distributed. *Kurtiella bidentata* ranges from Norway to west Africa and the Mediterranean (Carter, 2008). *Abra alba* is distributed from the Norwegian Sea and the Baltic, south to the Iberian Peninsula, into the Mediterranean and Black seas, and south along the coast of Africa to Senegal (Budd, 2007), and *Abra nitida* is distributed from Norway south to Mediterranean and north-west Africa (Hayward & Ryland, 1995b). *Melinna palmata* spreads from northern Spain with scattered records in the Mediterranean, Morocco, Black Sea and Arabian Gulf (Hayward & Ryland, 1995b). *Magelona filiformis* and *Magelona mirabilis* are widespread on the coasts of Britain and Northern Ireland (Rayment, 2007b; Richards, 2007), with the latter also extending to north-west Europe to Mediterranean (Hayward & Ryland, 1995b). *Thyasira flexuosa* does not occur in the southernmost part of the North Sea but is distributed from Norway to the Azores, and extends into the Mediterranean (Tillin & Tyler-Walters, 2014). However, *Thyasira* populations in the British Isles are restricted to areas where the bottom waters remain cool all year round (Jackson, 2007).

Kurtiella bidentata (studied as *Mysella bidentata*) was among the species that suffered high losses

that could be related to low temperatures in the Wadden Sea area in 1979, where the temperature was 3°C below average for 3 months (Beukema, 1979).

Short-term acute periods of extreme cold and icing conditions are likely to cause stress and some mortality in bivalve populations (Dame, 1996). For instance, during the 1978/79 winter which was very cold with severe ice conditions, water temperature in the outer Weser estuary, Germany, remained below 0°C on 45 successive days. Populations of the characteristic species of the benthos, including *Abra alba* were considerably damaged (Buhr, 1981). Equally, the abundance of *Magelona mirabilis* experienced a sharp decline following the severe winter of 1995/1996 in the Wadden Sea, the Netherlands (Armonies *et al.*, 2001), which was 2.7°C and 3.7°C below the mean water temperatures for the area (Strasser & Günther, 2001).

No specific information on temperature tolerances of *Melinna palmata* and *Thyasira* spp. was found. However, Dauvin (2000) reported *Abra-alba-Melinna* communities in the Bay of Morlaix, France, where bottom temperatures range from 8°C in winter to 16°C in summer, but during severe winters the temperature is < 6°C like in 1986.

Coyle *et al.* (2007) analysed temporal differences in benthic infaunal samples from the south-eastern Bering Sea shelf. Significant differences were observed for specific functional groups, namely carnivores, omnivores and surface detritivores which suggested a mechanistic link between temperature changes and infaunal biomass, both of which were elevated relative to warm periods due to elevated carbon flux to the benthos and exclusion of benthic predators on infaunal invertebrates by the cold bottom water on the shelf.

Sensitivity assessment. The characterizing species of the biotope are widely distributed and likely to occur both north and south of the British Isles, where typical surface water temperatures vary seasonally from 4-19°C (Huthnance, 2010). Although no information was found on the minimum temperature tolerated by the characterizing species, it is likely that *Kurtiella bidentata*, *Abra* spp., *Melinna palmata*, *Magelona* spp. and *Thyasira* spp. are able to resist a long-term decrease in temperature of 2°C. However, characterizing species may suffer some mortality as a result of an acute decrease in temperature, so resistance is therefore assessed as **Low** (25-75% loss) and resilience is likely to be **High,** so the biotopes are considered to have **Low** sensitivity to a decrease in temperature at the pressure benchmark level.

Salinity increase (local)

Low	High	Low
Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: NR C: NR

SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys are found within fully marine subtidal locations. The former also occurs occasionally in variable salinity (Connor *et al.*, 2004). However, it is highly unlikely that the biotopes would experience conditions of hypersalinity.

Sensitivity assessment. No direct evidence was found to assess the effects of changes in salinity and OBIS data (OBIS, 2014) was used as the basis of the assessment. The minimum and maximum range of salinities for the characterizing species are 18.6 - 38.6 pps for *Kurtiella bidentata*; 30.2-38.6 pps for *Abra alba*; 17.7–39.0 pps for *Melinna palmata*; 33.5-35.6 pps for *Magelona filiformis* and 31.8-39.1 pps for *Thyasira flexuosa*. This data suggests *Kurtiella bidentata* and *Melinna palmata* are able to tolerate wider salinity ranges, but no records of any of the species occurring in hypersaline conditions was found. It is therefore likely that key components of the biotopes communities would not be resistant of an increase in salinity to >40 psu, resulting in mortality of the characterizing species. Resistance is therefore assessed as **Low** (loss of 25-75%) but with low

confidence. Once normal conditions are resumed, resilience is probably **High** so that sensitivity is therefore assessed as **Low**.

Salinity decrease (local)	Low	High	Low
	Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: NR C: NR

SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys are found within fully marine subtidal locations. The former also occurs occasionally in variable salinity (Connor *et al.*, 2004).

According to OBIS data (OBIS, 2014), the minimum and maximum range of salinities for the characterizing species are 18.6 - 38.6 pps for *Kurtiella bidentata*; 30.2-38.6 pps for *Abra alba*; 17.7–39.0 pps for *Melinna palmata*; 33.5 - 35.6 pps for *Magelona filiformis* and 31.8-39.1 pps for *Thyasira flexuosa*. This data suggests *Kurtiella bidentata* and *Melinna palmata* are able to tolerate wider salinity ranges, which confirm records of *Kurtiella bidentata* (studied as *Mysella bidentata*) in Kinsale Harbour at salinities ranging from 19.3-35 S (O'Brien & Keegan, 2006). However, Gogina *et al.* (2010a) reported that *Kurtiella bidentata* (studied as *Mysella bidentata*) showed a strong positive correlation with salinity varying at a factor of 8.30-27.10 psu. According to Budd (2007), the change would be likely to cause inhibition of growth and reproduction and exposure to low salinity may result in some mortality of *Abra alba*. *Magelona mirabilis* occurs in the Baltic Sea (Fiege *et al.*, 2000) where salinity is typically lower than in the open ocean. It is likely that some populations of *Magelona mirabilis* are adapted to reduced salinity habitats, however, no information on the effects of an overall decrease in salinity were found. *Thyasira* spp. inhabit waters of reduced salinity with 25-30 psu being optimal. However, adults exposed to lower than optimal salinities produced non-viable or slow developing eggs (Jackson, 2007). There is insufficient information regarding the effects of salinity on adults.

Sensitivity assessment. SS.SMu.ISaMu.MelMagThys may occasionally occur in variable (18-35 psu) salinity probably due to the fact that the biotope occurs in sheltered marine inlets. The evidence presented suggests that not all characterizing species of both biotopes are likely to resist a decrease in salinity at the pressure benchmark level. Resistance is therefore assessed as **Low** (loss of 25-75%) but with low confidence. Once normal conditions are resumed, resilience is probably **High** so that sensitivity is therefore assessed as **Low**.

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

The hydrographic regime, including flow rates, is an important structuring factor in sedimentary habitats. The low energetic environments where the biotopes occur are therefore likely to be important in allowing for the development of the sandy mud substrata which characterize both biotopes. The most damaging effect of increased flow rate would be the erosion of the substratum as this could eventually lead to loss of the habitat. Increased water flow rates are likely to change the sediment characteristics in which the species live, primarily by resuspending and preventing deposition of finer particles (Hiscock, 1983). This may be particularly relevant for tube building species occurring in the biotopes such as characterizing species *Melinna palmata*. Furthermore, increased water flow rate may prevent settlement of larvae and therefore reduce recruitment. Mature adults buried at depth are likely to be unaffected as muddy substrata are particularly cohesive. Additionally, the consequent lack of deposition of particulate matter at the sediment surface would reduce food availability.

Decreased water movement would result in increased deposition of suspended sediment (Hiscock, 1983). An increased rate of siltation resulting from a decrease in water flow may result in an increase in food availability for the characterizing species and therefore growth and reproduction may be enhanced, but only if food was previously limiting.

Sensitivity assessment. Sand particles are most easily eroded and likely to be eroded at about 0.20 m/s (based on Hjulström-Sundborg diagram, Sundborg, 1956). Although having a smaller grain size than sand, clays and silts require greater critical erosion velocities because of their cohesiveness. SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThy occur in areas of very weak (negligible) and moderately strong (up to 1.5 m/s) tidal streams, respectively (Connor *et al.*, 2004). The characterizing species in these biotopes occur in a range of tidal regimes, varying from moderately strong to very weak (negligible - 1.5 m/s) (Tillin & Hull, 2013c; Tillin & Tyler-Walters, 2014 references therein). Although changes in water flow would be likely to change the sedimentary regime in the biotope, the cohesive nature of the sandy muds that characterize the biotope is likely to provide some protection to changes in water flow at the pressure benchmark. Additionally, the range of flow rates the characterizing species tolerate is likely to fall within the benchmark. Resistance and resilience are therefore assessed as **High** and the biotopes considered **Not Sensitive** to a change in water flow at the pressure benchmark level.

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

Some records of SS.SMu.ISaMu.KurAbr occur in the shallow subtidal and so may be vulnerable to an increase in the emergence regime, which may suppress the upper distribution of the biotope. On the other hand, the biotope could benefit from a decrease in the emergence regime.

Sensitivity assessment. A change in emergence regime may affect the biological community on the upper range of SS.SMu.ISaMu.KurAbr. However, the characterizing species live infaunally and are likely to be protected and the sublittoral element of the biotope is not likely to be lost. Mid-range populations are unlikely to be affected by a change in emergence regime so resistance and resilience are considered to be **High** and SS.SMu.ISaMu.KurAbr is assessed as **Not Sensitive** at the pressure benchmark level. Changes in emergence regime are **Not Relevant** to SS.SMu.ISaMu.MelMagThy, which is protected by the depth at which the biotope occurs.

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

Potentially the most damaging effect of increased wave action would be the erosion of the fine sediment substratum as this could eventually lead to loss of the habitat that characterizes the biotopes. Decreased exposure will probably lead to increased siltation and reduced grain size (muddy sediment). Changes in wave exposure may therefore influence the supply of particulate matter for tube building and feeding activities of the characterizing species. Food supplies may also be reduced, affecting growth and fecundity of the species. Strong wave action may cause damage or withdrawal of the siphons and delicate feeding structures, resulting in loss of feeding opportunities and compromised growth for the characterizing species. Additionally, individuals may be dislodged by scouring from sand and gravel mobilized by increased wave action (Budd, 2007; Rayment, 2007b). During winter gales along the North Wales coast, large numbers of *Abra alba* were cast ashore and over winter survival rate was as low as 7% in the more exposed locations (Rees *et al.*, 1977). Additionally, changes in wave exposure may also interfere with larval dispersal

of the characterizing species. Olivier *et al.* (1996) reported that the post-larvae and juveniles of *Abra alba* were most abundant in the near-bottom water stratum at flood tides. Therefore, increased wave action could result in enhanced resuspension and dispersal of early life stages, whereas a reduction in wave exposure may lead to a decrease in dispersal.

Magelona mirabilis is adapted to life in areas with strong currents, high wave exposure and unstable sediments (Lackshewitz & Reise, 1998). On the other hand, *Thyasira gouldi* lives in rather wave sheltered areas at the heads of sea lochs (Jackson, 2007). Increases in wave exposure may disrupt the sediment in which they live, cause continual displacement and physical damage to the shells which are thin and fragile.

Sensitivity assessment. Records indicated that the characterizing species occur in a range of wave exposures. *Kurtiella bidentata* occurs in sheltered, very sheltered, and moderately exposed; *Abra* spp. in extremely sheltered, very sheltered, sheltered, moderately exposed, exposed, extremely exposed and very exposed; *Melinna palmata* in extremely sheltered, very sheltered, sheltered; and *Thyasira flexuosa* in extremely sheltered, very sheltered, sheltered, and moderately exposed (Connor *et al.*, 2004). An increase in wave action may result in modification of the sediment and/or an increase in the probability that characterizing species would be removed by storms. However, as the biotope occurs in wave sheltered conditions, a further decrease in wave action is unlikely to be significant. However, an increase or decrease in wave height at the pressure benchmark (3-5% of significant wave height) is therefore considered to fall within the natural range of conditions experienced by mid-range populations of the biotopes, especially as the effect of wave action is reduced with depth. Resistance and resilience are therefore assessed as **High**, and the biotope is considered **Not Sensitive** at the benchmark level but with low confidence.

⚗ 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.

There is little or no information on the resistance of the key species in the biotopes. Experimental studies with various species suggests that polychaete worms are quite tolerant of heavy metals (Bryan, 1984). *Abra alba* can live in polluted sediments (Dauvin, pers. comm.), for example, near Calais where high densities of *Abra alba* were found in sediment containing 8 mg/g iron and 4 mg/g titanium (Dewarumez *et al.*, 1976, cited in Budd, 2007). The capacity of bivalves to accumulate heavy metals in their tissues, far in excess of environmental levels, is well known. Bryan (1984) states that Hg is the most toxic metal to bivalve molluscs while Cu, Cd and Zn seem to be most problematic in the field. In bivalve molluscs, Hg was reported to have the highest toxicity, mortalities occurring above 0.1-1 g/l after 4-14 days exposure (Crompton, 1997), toxicity decreasing from Hg > Cu and Cd > Zn > Pb and As > Cr (in bivalve larvae, Hg and Cu > Zn > Cd, Pb, As, and Ni > to Cr).

Boilly & Richard (1978) stated that the presence of *Magelona mirabilis* is indicative of sediments which have been contaminated with iron. Studies on a dredge spoil disposal site in the harbours of Boulogne and Dunkerque in France (Bourgain *et al.*, 1988) found higher densities of *Magleona*

mirabilis three months after the dumping of dredge spoil than after five months, that is, when the metal contamination of the sediments was higher. No information regarding the effect of other metals on this species was found.

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.

Suchanek (1993) reviewed the effects of oil spills on marine invertebrates and concluded that, in general, on soft sediment habitats, infaunal polychaetes, bivalves and amphipods were particularly affected. Sub-lethal concentrations may produce substantially reduced feeding rates and/or food detection ability, probably due to ciliary inhibition. Respiration rates may increase at low concentrations and decrease at high concentrations. Generally, contact with oil causes an increase in energy expenditure and a decrease in feeding rate, resulting in less energy available for growth and reproduction. However, the *Abra alba* population affected by the 1978 *Amoco Cadiz* benefited from the nutrient enrichment caused by the oil pollution. The biomass of the fine-sand community remained low in 1979, a year after the spill, owing to the decimation of the *Ampelisca* amphipod population, but the biomass then doubled as a result of an increase in *Abra alba* abundance in 1980 and *Abra alba* remained a dominant species over the 20 year duration, over which recovery of the community was monitored (Dauvin, 1998).

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.

Abra alba demonstrated alterations of its behaviour in response to exposure to marine sediments contaminated with pesticides (6000 ppm parathion, 200 ppm methyl parathion, 200 ppm malathion). No burrowing occurred in the most contaminated sediment, whilst burrowing was impaired in the moderately contaminated sediment with a median effective burrowing time ($ET_{(50)}$) of 9.0 (±3.0 - 28) minutes in comparison to a control time of 4.5 (±2.8 - 7.2) minutes (Møhlenberg & Kiørboe, 1983). There is no evidence relating directly to the effects of synthetic chemicals on the remaining characterizing species.

Radionuclide contamination	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 is available on which to assess this pressure.

Introduction of other substances	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**.

De-oxygenation	Medium	High	Low
	Q: Medium A: Medium C: Medium	Q: Low A: NR C: NR	Q: Low A: NR C: NR

A number of animals have behavioural strategies to survive periodic events of reduced dissolved oxygen. These include shell closure and reduced metabolic rate in bivalve molluscs and either decreased burrowing depth or emergence from burrows for sediment dwelling crustaceans, molluscs and annelids.

At oxygen concentrations below ca 0.4 mg O_2/l, *Kurtiella bidentata* eventually emerged from the substratum (Ockelmann & Muus, 1978). Nilsson & Rosenberg (1994) investigated hypoxic responses of benthic communities and reported *Kurtiella bidentata* (studied as *Mysella bidentata)* leaving the sediment at oxygen concentrations of 1.7 mg/l. According to the authors, this is a behaviour that occurs at hypoxic oxygen concentrations slightly higher than those causing mortality, suggesting high levels of stress caused to the organisms.

Abra alba is typically found in organically enriched sediments where it may be present in high densities (Dauvin & Gentil, 1989). Experimental examination of the interactions between eutrophication and oxygen deficiency (2.4-3.5 mg O_2/l over a 93 day experimental period) revealed that *Abra alba* became inefficient in its use of the available organic matter under prolonged conditions of hypoxia (Hylland *et al.*, 1996). *Abra alba* was also reported to be sensitive to lowered oxygen concentrations off the Swedish west coast (Rosenberg & Loo, 1988; Weigelt & Rumohr, 1986, both cited in Rees & Dare, 1993).

Melinna palmata has been reported to survive temporary periods of hypoxia, withstand large variation in oxygen concentration, and tolerate temporary anaerobiosis and the presence of hydrogen sulphides (Grehan, 1991).

Niermann *et al.* (1990) reported that *Magelona* sp. in a fine sand community in the German Bight area, exposed to regular seasonal hypoxia, remained abundant during a period of hypoxia (1-3 mg/l), and decreased slightly in abundance on resumption of normoxia (Rayment, 2008).

López-Jamar *et al.* (1987) stated that *Thyasira flexuosa* is adapted to living in reduced sediments and also is found in organically enriched sediments. However, Dando & Spiro (1993) found that numbers of the congeners *Thyasira equalis* and *Thyasira sarsi* decreased rapidly following the deoxygenation of bottom water in the deep basin of the Gullmar fjord in 1979-80.

Rosenberg *et al.* (1991) exposed benthic species from the NE Atlantic to oxygen concentrations of around 1 mg/l for several weeks, including species of small bivalves. After 11 days in hypoxic conditions, bivalve individuals were still alive, although individuals showed increased stretching of syphon out of the sediment. In a meta-analysis study of hypoxia, median sub-lethal oxygen concentrations reported in experimental assessments, although no specific data was reported for all the characterizing species of these biotopes, the thresholds of hypoxia for different benthic groups was LC50 1.42 mg/l for bivalves, and sub-lethal (SLC50) of 1.20 mg/l for annelids (Vaquer-Sunyer & Duarte, 2008). For *Kurtiella bidentata* (studied as *Mysella bidentata*), the median sub-lethal oxygen concentrations reported in experimental assessments was 1 mg/l, and for *Abra* spp. was 0.57 mg/l (Vaquer-Sunyer & Duarte, 2008).

Sensitivity assessment. Cole *et al.* (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l. Different species in the biotope will have varying responses to de-oxygenation. Based on the evidence presented, the characterizing species are likely to only be affected by severe deoxygenation episodes. However, some mortality of *Thyasira* spp. might occur in near anoxic (0% oxygen) conditions. Resistance to deoxygenation is therefore assessed as **Medium.** Resilience of the biotopes is likely to be **High** and the biotopes are

therefore considered to have **Low** sensitivity to exposure to dissolved oxygen concentration of less than or equal to 2 mg/l for 1 week.

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

Increased nutrients are most likely to affect abundance of phytoplankton which may include toxic algae (OSPAR, 2009). This primary effect resulting from elevated nutrients will impact upon other biological elements or features (e.g. toxins produced by phytoplankton blooms or deoxygenation of sediments) and may lead to 'undesirable disturbance' to the structure and functioning of the ecosystem. With enhanced primary productivity in the water column, organic detritus that falls to the seabed may also be enhanced, which may be utilized by the deposit feeders in the community.

In a sewage dumping region of the North Sea, a great increase in the abundance of *Abra alba* occurred in much of the dumping area because of the ecological adaptations of the species enabled it to exploit the greatly increased supply of nutrients (Caspers, 1981). For example, the *Amoco Cadiz* oil spill in March 1978 caused vast disturbance to the fine-sand communities of the Bay of Morlaix, France (Dauvin, 1982). Drastic qualitative and quantitative changes in species abundance, diversity and biomass were recorded after the spill. However, the *Abra alba* population persisted in the disturbed environment under eutrophic conditions and as an 'opportunistic species' (Hily & Le Bris, 1984), rapidly adapting its reproductive strategy to three spawnings per year. Increased growth and abundance was attributable to increased food availability and vacant ecological niches (Dauvin & Gentil, 1989).

As a surface deposit feeder, *Magelona mirabilis* relies on a supply of organic matter at the sediment surface. Increased nutrient levels in the water column would be expected to result in increased deposition of organic matter at the sediment surface, and therefore moderate nutrient enrichment may be beneficial to *Magelona mirabilis*. Indeed, Kröncke (1990) postulated that the increase in certain species, including *Magelona* sp., on the Dogger Bank between 1951 and 1987 may be due to eutrophication. However, Niermann (1996) noted that *Magelona* sp. decreased in abundance following a nutrient enrichment event in the North Sea, probably because the species were adapted to living in sediments with low or moderate amounts of organic carbon.

Enrichment from pulp mills is believed to have been the cause of the death of two populations of *Thyasira* spp. in west Scotland sea lochs. *Thyasira flexuosa* was recorded at densities of up to 4000 per square metre in enriched areas (Jackson, 2007).

In a report to identify seabed indicator species to support implementation of the EU habitats and water framework directives *Kurtiella bidentata*, *Melinna palmata* and *Thyasira* spp. were reported as likely to be favoured by nutrient enrichment, whereas *Abra* spp. and *Magelona* spp. were assessed as intolerant (Hiscock *et al.*, 2005a). The community, and hence the biotopes, may change to one dominated by nutrient enrichment resistant species, in particular polychaete worms.

However, the biotopes are considered to be **Not Sensitive** at the pressure benchmark that assumes compliance with WFD criteria for good status.

Organic enrichment	Low	High	Low
	Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: NR C: NR

In a sewage dumping region of the North Sea, a great increase in the abundance of *Abra alba* occurred in much of the dumping area because of the ecological adaptations of the species enabled it to exploit the greatly increased supply of nutrients (Caspers, 1981). For example, the *Amoco Cadiz* oil spill in March 1978 caused vast disturbance to the fine-sand communities of the Bay of Morlaix, France (Dauvin, 1982). *Abra alba* persisted in the disturbed environment under eutrophic conditions and as an 'opportunistic species' (Hily & Le Bris, 1984), with increased growth and abundance attributed to increased food availability and vacant ecological niches (Dauvin & Gentil, 1989 cited in Budd, 2007).

The spread of *Melinna palmata* in the Romanian sublittoral described by Gomoiu (1982, cited from Grehan, 1991) was correlated with an increase in siltation following increased eutrophication linked phytoplankton blooms. Guillou & Hily (1983), in their study on the Bay of Brest, considered that the population benefited through enhanced growth from organic enrichment through sewage disposal.

As a surface deposit feeder, *Magelona mirabilis* relies on a supply of organic matter at the sediment surface. Increased nutrient levels in the water column would be expected to result in increased deposition of organic matter at the sediment surface. Kröncke (1990) postulated that the increase in certain species, including *Magelona* sp., on the Dogger Bank between 1951 and 1987 may be due to eutrophication. However, Niermann (1996) noted that *Magelona* sp. decreased in abundance following a nutrient enrichment event in the North Sea, probably because the species were adapted to living in sediments with low or moderate amounts of organic carbon.

Thyasira spp. are characteristic of organically enriched offshore sediments with *Capitella capitata* (Connor *et al.*, 2004) and have been identified as a 'progressive' species, i.e. one that shows increased abundance under slight organic enrichment (Leppakoski, 1975, cited in Gray, 1979).

Borja *et al.* (2000) and Gittenberger & Van Loon (2011) assigned *Abra alba*, *Melinna palmata* and *Thyasira flexuosa* to their Ecological Group III 'species tolerant to excess organic matter enrichment; these species may occur under normal conditions, but their populations are stimulated by organic enrichment (slight unbalance situations)'. *Kurtiella bidentata* (as *Mysella bidentata*) and *Magelona mirabilis* were characterized as AMBI Group I – 'species very sensitive to organic enrichment and present under unpolluted conditions (initial state)'.

Sensitivity assessment. No direct evidence of the characterizing species' specific tolerances to organic enrichment was found. The evidence presented suggests that the majority of the characterizing species in the biotopes are likely to be able to utilize additional organic load as food. However, the evidence also suggests that *Kurtiella bidentata* and *Magelona* spp. May experience decreases in abundance as a result of organic enrichment, which can lead to shifts in community composition towards one dominated by tolerant species, such as polychaete worms (Pearson & Rosenberg, 1978). Additionally, Forrest *et al.* (2009) identified that the recovery of muddy sediments beneath fish farms from enrichment can be highly variable and may be many years at poorly flushed sites, suggesting that the low energy environments that characterize these biotopes may allow for prolonged periods of organic load sedimentations and enhance the adverse effects to sensitive characterizing species. Resistance is therefore assessed as **Low** (loss 25-75%), but with low confidence. Resilience is likely to the **High** and the overall sensitivity of the biotopes judged as **Low.**

Ⱶ 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

If the sediment that characterizes the biotopes were replaced with rock substrata, this would represent a fundamental change to the physical character of the biotopes. The characterizing species would no longer be supported and the biotopes would be lost and/or reclassified.

Sensitivity assessment. Resistance to the pressure is considered **None**, and resilience **Very Low**, given the permanent nature of this pressure. Sensitivity has been assessed as **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 sediment type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

Records indicate that SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys occur in cohesive sandy muds (Connor *et al.*, 2004). The characterizing species within these biotopes have wide ranges of sediment preferences. *Kurtiella bidentata* lives in muddy sand or fine gravel (Carter, 2008); *Abra* spp. prefer mud, muddy gravel, muddy sand, sandy mud (Budd, 2007); *Magelona* spp. occur in coarse clean sand and fine clean sand (Rayment, 2007b); and *Thyasira* spp. prefer mud, muddy sand, sandy mud (Jackson, 2007). *Melinna palmata* lives in a mucus lined tube covered with sediment particles in mud substrata (Fauchald & Jumars, 1979).

Sensitivity assessment. In SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys, a change in Folk class from mud and sandy mud to sand or muddy sand would probably not affect the characterizing species which all have habitats preferences that would fall within this range. However, a change in one Folk class to gravelly mixed sediment is likely to result in some of the characterizing species not being supported anymore, and a reclassification of the biotopes. Resistance is therefore assessed as **None** and resilience is considered **Very Low** given the permanent nature of this pressure. Sensitivity is therefore assessed as **High**.

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

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment, which may be anoxic and/or of a

different character, and lead to changes in the topography of the area (Dernie *et al.*, 2003). Any remaining species, given their new position at the sediment / water interface, may be exposed to unsuitable conditions. Newell *et al.* (1998) state that removal of 0.5 m depth of sediment is likely to eliminate benthos from the affected area. Some epifaunal and swimming species may be able to avoid this pressure. Removal of 30 cm of sediment will remove species that occur at the surface and within the upper layers of sediment, such as the characterizing species of these biotopes. For example, *Abra alba* is a shallow burrower and has a fragile shell (Tebble, 1976). *Thyasira* species are found 2-8 cm below the sediment surface (Dando & Southward, 1986)

Recovery of the sedimentary habitat would occur via infilling, although some recovery of the biological assemblage may take place before the original topography is restored, if the exposed, underlying sediments are similar to those that were removed. Newell *et al.* (1998) indicated that local hydrodynamics (currents and wave action) and sediment characteristics (mobility and supply) strongly influence the recovery of soft sediment habitats.

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotopes so resistance is assessed as **None**. SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys occur in low energy environments, so resilience is therefore judged as **Medium**, based on the recruitment dispersal limitation of the characterizing species (see resilience section). Sensitivity has been assessed as **Medium.**

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

The characterizing species of SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys are infaunal and hence have some protection against surface disturbance. Bivalves and other species require contact with the surface for respiration and feeding. Siphons and delicate polychaete feeding structures may be damaged or withdrawn as a result of surface disturbance, resulting in loss of feeding opportunities and compromised growth.

Abra alba is a shallow burrower with a fragile shell (Tebble, 1976), and has been considered amongst the list of bivalve species most vulnerable to trawling (Bergmann & Van Santbrink, 2000) who reported between <0.5% and 18% mortality of *Abra alba* due to trawling in the southern North Sea. However, the small size of *Abra alba* relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through (Rees & Dare, 1993). This is likely to also be the case for small infaunal bivalve *Kurtiella bidentata*. *Magelona mirabilis* is a soft bodied organism which exposes its palps at the surface while feeding. The species usually lives within a few centimetres of the sediment surface. Physical disturbance, such as dredging or dragging an anchor, would likely cause physical damage to *Magelona mirabilis*. *Thyasira* spp. are small bivalves, the shells are thin and fragile and abrasion is likely to lead to damage and mortality within the population depending on the force (Jackson, 2007). Sparks-McConkey & Watling (2001) found that trawler disturbance resulted in a decline of *Thyasira flexuosa* in Penobscot Bay, Maine. However, the population recovered after 3.5 months.

Furthermore, SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThys occur in cohesive sandy muds (Connor *et al.*, 2004). Abrasion events caused by a passing fishing gear, or scour by objects on the seabed surface are likely to have marked impacts on the substratum and cause turbulent resuspension of surface sediments. When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs.,

cited in Jennings & Kaiser, 1998). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & Van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures). The effects of trawling on infauna are greater in areas with low levels of natural disturbance compared to areas of high natural disturbance (e.g. Hiddink *et al.*, 2006). In a meta-analysis of the impacts of different fishing activities on the benthic biota of different habitats, muddy sands were found to be vulnerable to the impacts of fishing activities, with recovery times predicted to take years (Kaiser *et al.*, 2006). The long recovery time for muddy sands is due to the fact that these habitats are mediated by a combination of physical, chemical and biological processes (compared to sand habitats which are dominated by physical processes and recovery time takes days to months).

Sensitivity assessment. The characterizing species live infaunally and are considered to have some protection against surface disturbance. However, the evidence presented suggests that soft bodied organisms and fragile shells are likely to be damaged and removed by abrasion. Resistance to abrasion is therefore considered **Low**. Resilience of the biotopes is likely to be **High**. The biotopes are therefore considered to have **Low** sensitivity to abrasion or disturbance of the surface of the seabed.

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

Activities that disturb the surface and penetrate below the surface would remove /damage infaunal species such as the characterizing species within the direct area of impact. The footprint of the impact will depend on the type of gear used (Hall *et al.*, 2008).

Bergman & Van Santbrink (2000) estimated the direct mortality of benthic macrofauna caused by the single pass of commercial beam and otter trawls. The results showed that a single pass of a 4 m or 12 m beam trawl or an otter trawl, in shallow sandy areas and deep silty sand areas (with 3-10% silt) in the North Sea caused a mortality of 20-65% of bivalves and 5-40% of gastropods, starfish, small-medium sized crustaceans and annelid worms. Of the characterizing species mentioned, mortality of *Kurtiella bidentata* (studied as *Mysella bidentata*) was reported as 4%, and *Magelona* sp. 30%. Some mortality was not caused directly by the passage of the trawl, but instead by disturbance, exposure and subsequent predation. Ball *et al.* (2000) reported on the short-term effects of fishing on benthos from a mud patch in the north-western part of the Irish Sea investigated in 1994–1996 by means of samples taken both before and shortly after (ca 24 hr) fishing activity. *Kurtiella bidentata* (studied as *Mysella bidentata*) was one of the species that was common at the inshore site and for which estimates of mortality were calculated and was uncommon or totally absent on the offshore fishing ground. Direct mortality from passage of an otter trawl was estimated as 70%. The delicate shells of *Abra* spp. are vulnerable to physical damage (e.g. by otter boards), but small size relative to meshes of commercial trawls may ensure survival of at least a moderate proportion of disturbed individuals which pass through (Rees & Dare, 1993). Equally, *Thyasira* spp. also have delicate shells and are likely to be vulnerable to physical disturbance. Following experimental beam trawl disturbance in an area that had previously been closed to fishing, populations of *Melinna palmata* increased by 41% (Tuck *et al.*, 1998). The area was repeatedly disturbed over an 18 month period and recovery tracked for a further 18 months.

Furthermore, penetrative events caused by a passing fishing gear are also likely to have marked impacts on the substratum and cause turbulent resuspension of surface sediments (see abrasion pressure). When used over fine muddy sediments, trawls are often fitted with shoes designed to prevent the boards digging too far into the sediment (M.J. Kaiser, pers. obs., cited in Jennings & Kaiser, 1998). Trawling can create suspended sediment plumes up to 10 m above the bottom (Churchill, 1989 cited in Clarke & Wilber, 2000). Shrimp trawlers in Texas have increased suspended sediment concentrations to between 100 and 550 mg/l at 2 m above the bottom and 100 m astern of trawls (Schubel *et al.*, 1978, cited in Clarke & Wilbur, 2000). The effects may persist for variable lengths of time depending on tidal strength and currents and may result in a loss of biological organization and reduce species richness (Hall, 1994; Bergman & Van Santbrink, 2000; Reiss *et al.*, 2009) (see change in suspended solids and smothering pressures). A meta-analysis of over 100 experimental fishing impact studies showed that beam trawling, scallop dredging and otter trawling all had significant short-term impacts in muddy sand habitats, with most severe effect on suspension feeders (Kaiser *et al.*, 2006). Jennings *et al.* (2001) found that trawling in the muddy sand region led to significant decreases in infaunal biomass and production in the North Sea, with the abundance of larger individuals depleted more than smaller ones.

Sensitivity assessment. A large proportion of the characterizing species in these biotopes is likely to be lost or severely damaged, depending on the scale of the activity (see abrasion pressure). Therefore, a resistance of **Low** is suggested. Muddy sand habitats have been reported as having the longest recovery times, whilst mud habitats had an 'intermediate' recovery time (compared to clean sand communities which had the most rapid recovery rate) (Dernie *et al.*, 2003). Resilience is probably **High** and, therefore, the biotopes' sensitivity to this pressure if likely to be **Low**.

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

For most benthic deposit feeders, food is suggested to be a limiting factor for populations (Levinton, 1979; Hargrave, 1980). Consequently, an increase in suspended particulates and subsequent increased deposition of organic matter in sheltered environments where sediments have high mud content will increase food resources to deposit feeders. Burrowing infauna are unlikely to be affected by an increase in suspended sediment. There may be possible clogging of feeding organs in suspension feeders and there may be some energetic cost to clear their feeding and respiration organs. However, characterizing bivalve species such as *Kurtiella bidentata* and *Abra* spp. are able to switch between feeding methods (Carter, 2008; Budd, 2007). If the suspended sediment has a high organic content, some suspension feeding organisms may benefit. Increased siltation may benefit deposit feeders, such as characterizing species *Magelona* spp.. An increase in turbidity resulting from an increase in suspended solids may reduce primary production in the water column and on sediment surfaces therefore reducing the availability of diatom food, both for suspension feeders and deposit feeders. Deposit feeders and tube builders rely on deposition of suspended sediment. A decrease in suspended sediment will reduce this supply and therefore may compromise growth and reproduction.

Lethal effects on *Kurtiella bidentata* are considered unlikely given the occurrence of this species in estuaries where turbidity is frequently high from suspended organic and inorganic matter. *Melinna palmata* has been reported to increase in response to decreased turbidity (Warwick *et al.*, 1991, cited in Hiscock *et al.*, 2004), suggesting that increased turbidity may be detrimental to this species. *Thyasira* is the only known obligate suspension feeder of the characterizing species, so additional cleaning costs may be incurred for feeding apparatus but this are not considered to be lethal

(Jackson, 2007).

According to Widdows *et al.* (1979), growth of filter-feeding bivalves may be impaired at suspended particulate matter (SPM) concentrations >250 mg/l. For instance, the abundance of *Abra alba* declined over two years within 1 km of an outfall pipe discharging fine-grained mineral waste from the china-clay industry at a rate of 450,000 tons per year to Mevagissey Bay, Cornwall. However, it was argued that persistent sediment instability was the more significant source of stress to the predominantly deposit-feeding community than the suspended sediment concentration (Probert, 1981).

Sensitivity assessment. The main environmental effects of increased turbidity levels as a result of increase in suspended solids are a reduction in penetration of light into the water column, suspended-sediment impacts on filter-feeding organisms and increased deposition of particulates in low-energy environments. Buchanan & Moore (1986) found that a decline in quantities of organic matter changed the infauna of a deposit feeding community which is essentially food limited. This may lead to a shift in community structure with increased abundance of deposit feeders and a lower proportion of suspension feeders (as feeding is inhibited where suspended particulates are high and the sediment is destabilised by the activities of deposit feeders (Rhoads & Young, 1970). The evidence presented suggests that the characterizing species are likely to resist a change in one rank on the WFD (Water Framework Directive) scale e.g. from clear to intermediate. But some species, such as *Melinna palmata*, *Thyasira* spp. and *Abra* spp., would be adversely impacted where a change from intermediate to medium (100-300 mg/l) turbidity occurred. Resistance is therefore assessed as **Low**. Resilience is likely to be **High**, so the biotopes are considered to have **Low** sensitivity to a change in suspended solids at the pressure benchmark level.

Smothering and siltation rate changes (light)	High	High	Not sensitive
	Q: Low A: NR C: NR	Q: High A: High C: High	Q: Low A: NR C: NR

Bijkerk (1988 cited from Essink, 1999) indicated that the maximal overburden through which small bivalves could migrate was 20 cm in sand for *Donax* and approximately 40 cm in mud for *Tellina* sp. and approximately 50 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. Powilleit *et al.* (2009) studied responses to smothering for three bivalves; *Arctica islandica*, *Limecola balthica* and *Mya arenaria*. These successfully burrowed to the surface of a 32 – 41 cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. These high escape potentials could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. In comparison to a thick coverage, thin covering layers (i.e. 15 - 16 cm and 20 cm) increased the chance of the organisms to reach the sediment surface after burial. This suggests that characterizing bivalve species such as *Kurtiella bidentata*, *Abra* spp. and *Thyasira* spp. are likely to be able to burrow through similar overburdens, although sudden smothering with 5 cm of sediment would temporarily halt feeding and respiration, compromising growth and reproduction owing to energetic expenditure. Furthermore, *Thyasira flexuosa* have highly extensible feet (Dando & Southward, 1986) allowing them to construct channels within the sediment and to burrow to 8 cm depth.

Melinna palmata was reported to colonize the Bay of Seine, France, following increase of the fine sediment in the eastern part of the bay (Dauvin *et al.*, 2007). The tubes of *Melinna palmata* project above the surface and this will provide some protection against siltation. The effects of siltation will depend on the amount and rate that particles are added. The species is sedentary and adults

are judged unlikely to have any mechanism to escape from large inputs. The spread of *Melinna palmata* in the Romanian sublittoral described by Gomoiu (1982, cited from Grehan, 1991) was correlated with an increase in siltation following increased eutrophication linked phytoplankton blooms. As a surface deposit feeder, *Melinna palmata* lives in accreting environments and are likely to be able to tolerate low and constant levels of siltation.

Magelona mirabilis lives infaunally in fine sand and moves by burrowing. It deposit feeds at the surface by extending contractile palps from its burrow. An additional 5 cm layer of sediment would result in a temporary cessation of feeding activity, and therefore growth and reproduction are likely to be compromised. However, *Magelona mirabilis* would be expected to quickly relocate to its favoured depth (Rayment, 2007b).

The character of the overburden is an important factor determining the degree of vertical migration. Individuals are more likely to escape from a covering similar to the sediments in which the species is found than a different type.

Sensitivity assessment. Beyond re-establishing burrow openings or moving up through the sediment, there is evidence of synergistic effects on burrowing activity of marine benthos and mortality with changes in time of burial, sediment depth, sediment type and temperature (Maurer *et al.*, 1986). However, the biotopes are likely to resist smothering at the benchmark level since the majority of associated fauna are burrowing infauna. Resistance is therefore assessed as **High**, and resilience is also **High** (by default), so that the biotopes are considered **Not Sensitive** to a 'light' deposition of up to 5 cm of fine material added to the seabed in a single, discrete event.

Smothering and siltation rate changes (heavy)	Low	High	Low
	Q: Low A: NR C: NR	Q: Low A: NR C: NR	Q: Low A: NR C: NR

Bijkerk (1988, cited from Essink, 1999) indicated that the maximal overburden through which small bivalves could migrate was 20 cm in sand for *Donax* and approximately 40 cm in mud for *Tellina* sp. and approximately 50 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. Powilleit *et al.* (2009) studied responses to smothering for three bivalves; *Arctica islandica, Limecola balthica* and *Mya arenaria*. These successfully burrowed to the surface of a 32–41 cm deposited sediment layer of till or sand/till mixture and restored contact with the overlying water. These high escape potentials could partly be explained by the heterogeneous texture of the till and sand/till mixture with 'voids'. In comparison to a thick coverage, thin covering layers (i.e. 15 - 16 cm and 20 cm) increased the chance of the organisms to reach the sediment surface after burial. This suggests that characterizing species *Kurtiella bidentata, Abra* spp. and *Thyasira* spp. are likely to be able to burrow through similar overburdens, although sudden smothering with 30 cm of sediment would temporarily halt feeding and respiration, compromising growth and reproduction owing to energetic expenditure. Furthermore, *Thyasira flexuosa* have highly extensible feet (Dando & Southward, 1986) allowing them to construct channels within the sediment and to burrow to 8 cm depth.

Melinna palmata was reported to colonize the Bay of Seine, France, following increase of the fine sediment in the eastern part of the bay (Dauvin *et al.*, 2007). The tubes of *Melinna palmata* project above the surface and this will provide some protection against siltation. The effects of siltation will depend on the amount and rate that particles are added. The species is sedentary and adults are judged unlikely to have any mechanism to escape from large inputs. Where inputs are at low rates and similar to background sediments then adults may be able to extend tubes to reach the

surface to feed. The spread of *Melinna palmata* in the Romanian sublittoral described by Gomoiu (1982, cited from Grehan, 1991) was correlated with an increase in siltation following increased eutrophication linked phytoplankton blooms. As a surface deposit feeder, *Melinna palmata* lives in accreting environments and are likely to be able to tolerate low and constant levels of siltation.

Magelona mirabilis lives infaunally in fine sand and moves by burrowing. It deposit feeds at the surface by extending contractile palps from its burrow. An additional 30 cm layer of sediment would result in cessation of feeding activity, and therefore growth and reproduction are likely to be compromised (Rayment, 2007b).

The character of the overburden is an important factor determining the degree of vertical migration. Individuals are more likely to escape from a covering similar to the sediments in which the species is found than a different type.

Sensitivity assessment. Beyond re-establishing burrow openings or moving up through the sediment, there is evidence of synergistic effects on burrowing activity of marine benthos and mortality with changes in time of burial, sediment depth, sediment type and temperature (Maurer *et al.*, 1986). Bivalve and polychaete species have been reported to migrate through depositions of sediment greater that the benchmark (30 cm of fine material added to the seabed in a single discrete event) (Bijkerk, 1988; Powilleit *et al.*, 2009; Maurer *et al.*, 1982). However, it is not clear whether the characterizing species are likely to be able to migrate through a maximum thickness of fine sediment because muds tend to be more cohesive and compacted than sand. Some mortality of the characterizing species is likely to occur. Resistance is therefore assessed as **Low** (25-75% loss) and resilience as **High** and the biotopes are considered to have **Low** sensitivity to a 'heavy' deposition of up to 30 cm of fine material in a single discrete event.

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 is available on which to assess this pressure.

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 in the biotopes may respond to vibrations from predators or excavation by retracting their palps into their tubes or by burrowing deeper into the sediment. However, the characterizing species are unlikely to be affected by noise pollution and so the biotopes are assessed as **Not Sensitive**.

Introduction of light or shading	Not relevant (NR)	Not relevant (NR)	Not sensitive
	Q: NR A: NR C: NR	Q: NR A: NR C: NR	Q: NR A: NR C: NR

SS.SMu.ISaMu.KurAbr and SS.SMu.ISaMu.MelMagThy are sublittoral biotopes (Connor *et al.*,

2004). Although eelgrass *Zostera marina* may occasionally occur in SS.SMu.ISaMu.KurAbr in low densities (Connor *et al.*, 2004), the biotopes are not characterized by the presence of primary producers and therefore, not directly dependent on sunlight.

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 to biotopes restricted to open waters.

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

The characterizing species of the biotopes live infaunally, so are likely to have poor or no visual perception and unlikely to be affected by visual disturbance such as shading.

🐛 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

The important characterizing species in the biotopes are not cultivated or likely to be translocated. This pressure is therefore considered **Not Relevant**.

Introduction or spread of invasive non-indigenous species	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

Sediments where the biotopes are found could be colonized by the Pacific oyster (*Magallana gigas*) and the slipper limpet (*Crepidula fornicata*), which have great potential of leading to smothering effects. The slipper limpet was first recorded in Northern Ireland at Belfast Lough in 2009 (McNeill *et al.*, 2010), and may form chains of up to 12 animals sometimes forming dense carpets which can smother bivalves and alter the seabed, making the habitat unsuitable for larval settlement. Pacific oysters were first brought to Northern Ireland as part of aquaculture development. They have now been grown in Northern Ireland since the early 1970s. Populations of *Cassostrea gigas* have formed solid reefs in soft sediment habitats such as the mudflats of the Wadden Sea (Ruesink *et al.*, 2005; Kochmann *et al.*, 2008, cited in OSPAR, 2009).

The Manila clam (*Tapes philippinarium*), which was introduced to Poole Harbour for aquaculture in 1998, has become a naturalised population on the intertidal mudflats, occurring at densities of 60

clams/m^2 in some locations within the harbour (Jensen *et al.*, 2007 cited in Caldow *et al.*, 2007). Densities of clam species such as *Cerastoderma edule* increased since the introduction of the Manila clam, so Caldow *et al.* (2007) concluded that within Poole Harbour there was no evidence yet of species replacement by the Manila clam.

Sensitivity assessment. Subtidal muds are considered highly sensitive to non-native invasive species due to the potential for habitat and ecological change when these are established and the difficulty in removing them. However, no evidence can be found on the impacts of INNS on the characterizing species within these biotopes. For this reason the effect of this pressure has been given as **No Evidence**. Literature for this pressure should be revisited.

Introduction of microbial pathogens	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

More than 20 viruses have been described for marine bivalves (Sinderman, 1990). Bacterial diseases are more significant in the larval stages and protozoans are the most common cause of epizootic outbreaks that may result in mass mortalities of bivalve populations. Parasitic worms, trematodes, cestodes and nematodes can reduce growth and fecundity within bivalves and may in some instances cause death (Dame, 1996).

A viral infection of the mutualist bacterium living on the gills of *Thyasira gouldi* was suggested as the reason for a major decline in the Loch Etive population (Jackson, 2007,) but no information specifically concerning the effects of microbial pathogens and parasites on the viability of the characterizing species was found.

Sensitivity assessment. No direct evidence of the biotopes being affected by the introduction of microbial pathogens was found as with which to assess this pressure.

Removal of target 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

It is extremely unlikely that any of the species indicative of sensitivity would be targeted for extraction. This pressure is therefore considered **Not Relevant**.

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

Direct, physical impacts are assessed through the abrasion and penetration of the seabed pressures, while this pressure considers the ecological or biological effects of by-catch. Species in these biotopes, including the characterizing species, may be damaged or directly removed by static or mobile gears that are targeting other species (see abrasion and penetration pressures). Loss of these species would alter the character of the biotope resulting in re-classification, and would alter the physical structure of the habitat resulting in the loss of the ecosystem functions such as secondary production performed by these species.

Sensitivity assessment. Removal of the characterizing species would result in the biotopes being lost or re-classified. Therefore, the biotopes are considered to have a resistance of **Low** to this pressure and to have **High** resilience, resulting in the sensitivity being judged as **Low**.

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