Brissopsis lyrifera and *Amphiura chiajei* in circalittoral mud

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

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2016-03-28

This review can be cited as:
De-Bastos & Budd 2016. [Brissopsis lyrifera] and [Amphiura chiajei] in circalittoral mud. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom.
DOI https://dx.doi.org/10.17031/marlinhab.139.1

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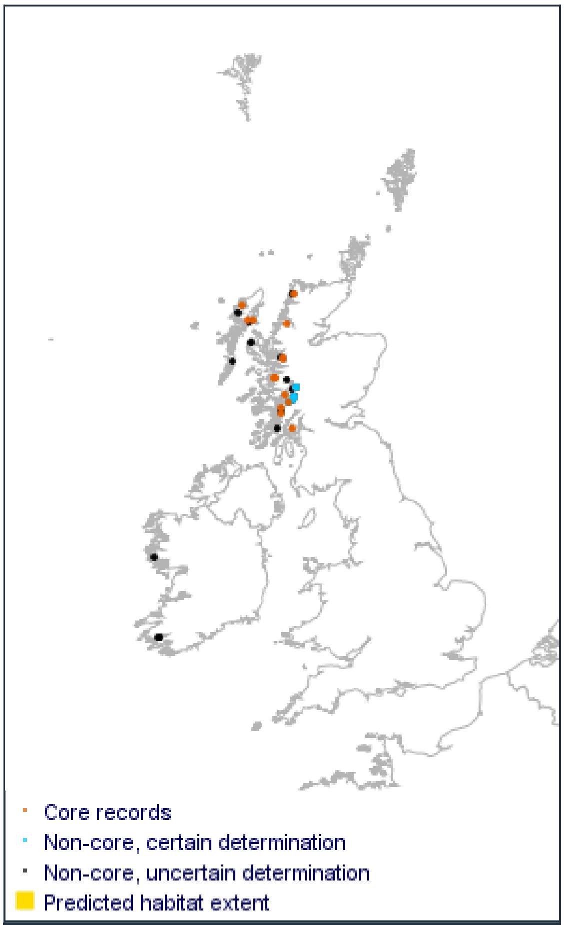

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Eliane De-Bastos & Georgina Budd **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.363	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud
JNCC 2015	SS.SMu.CFiMu.BlyrAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud
JNCC 2004	SS.SMu.CFiMu.BlyrAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud
1997 Biotope	SS.CMU._.BriAchi	*Brissopsis lyrifera* and *Amphiura chiajei* in circalittoral mud

Description

Mud in deep offshore, or shallower stable nearshore, waters can be characterized by the urchin *Brissopsis lyrifera* and the brittlestar *Amphiura chiajei*. Where intense benthic dredge fishing activity occurs, populations of the indicator species, *Brissopsis lyrifera* may be depressed, although broken tests may still remain (E.I.S. Rees pers. comm. 1997; M. Costello pers. comm. 1997). Low numbers of the seapen *Virgularia mirabilis* may be found in many examples of this biotope. In addition, in certain areas of the UK such as the northern Irish Sea, this community may also contain *Nephrops* *norvegicus* and can consequently be the focus for fishing activity (Mackie *et al*., 1995). Infaunal species in this community are similar to those found in SpnMeg and include the polychaetes *Nephtys hystricis*, *Pectinaria belgica*, *Glycera* spp. and *Lagis koreni* and the bivalves *Myrtea spinifera* and *Nucula sulcata*. This community is the 'Boreal Offshore Mud Association' and '*Brissopsis* - *Chiajei*' communities described by other workers (Petersen, 1918; Jones, 1950). (Information taken from the Marine Biotope Classification for Britain and Ireland, Version 15.03: Connor *et al*., 2004).

Depth range

20-30 m, 30-50 m, 50-100 m

Additional information

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Listed By

- none -

Further information sources

Search on:

G G JNCC

Habitat review

Ecology

Ecological and functional relationships

- The presence of the characterizing and other species in this biotope is primarily determined by the occurrence of a suitable substratum rather than by interspecific interactions. *Brissopsis lyrifera* and *Amphiura chiajei* are functionally dissimilar and are not necessarily associated with each other but for their occurrence in the same muddy sediments. Hollertz *et al*. (1998) found evidence of indirect competition between *Brissopsis lyrifera* and *Amphiura chiajei*. Decreased body and gonad growth rates in *Amphiura chiajei* were reported in the presence of *Brissopsis lyrifera*, possibly indicating that *Brissopsis lyrifera* may be a superior competitor for food, or that the deeper burrowing activity of *Brissopsis lyrifera* disturbs *Amphiura chiajei*
- Bioturbation is particularly important in controlling chemical, physical and biological processes in marine sediments, especially when the influences of physical disturbances such as wave action or strong currents are minimized (Widdicombe & Austen, 1999). Hollertz (1998) estimated the turnover rate of sediment by *Brissopsis lyrifera* to be 8.0 cm per hour, thus it is likely that *Brissopsis lyrifera* plays an important role in the enhancement of species heterogeneity in an otherwise largely homogenous environment. *Brissopsis lyrifera* is reported to increase meiobenthic species abundance and diversity and have a density dependent effect upon the community structure of meiobenthic nematode communities (Widdicombe & Austen, 1998; Austen & Widdicombe, 1998). The presence of *Brissopsis lyrifera* also significantly influenced nutrient fluxes of nitrogen and phosphorus at the sediment-water interface, owing to its burrowing activity promoting oxygenation of the substrata. Also with a high density of *Brissopsis lyrifera* (71 individuals per m), silicate precipitation from the water column was observed to increase, probably owing to continuous bioturbation exposing a greater volume of sediment to the light, enabling autotrophs such as diatoms and radiolarians, to exist deeper in the substrata rather than as a thin surface film, increasing the biological demand for dissolved silicates (Widdicombe & Austen,1998)
- The burrowing and feeding activities of *Brissopsis lyrifera* and *Amphiura chiajei* and other macrofauna, are likely to modify the fabric and increase the mean particle size of the upper layers of the substrata by aggregation of fine particles into faecal pellets. Such actions create a more open sediment fabric with a higher water content which affects the rigidity of the seabed (Rowden *et al*., 1998). Such alteration of the substratum surface can affect rates of particle resuspension.
- Most of the species living in deep mud biotopes are generally cryptic so are protected to some extent from visual surface predators. However, the arm tips of *Amphiura chiajei* are an important food source for demersal fish and *Nephrops norvegicus* providing significant energy transfer to higher trophic levels. Munday (1993) examined the occurrence and significance of arm regeneration in *Amphiura chiajei* in a population from western Ireland. Biomass assays revealed that regenerative tissue accounted for up to 57.9% of total body weight with an overall mean of 4.21±0.3 arms per individual regenerating. Increased nutrients leading to increased primary production may contribute to an accumulation of hydrophobic contaminants in *Amphiura chiajei* and their transfer to higher trophic levels (Gunnarsson & Skold, 1999).
- *Nephrops norvegicus* is eaten by a variety of bottom-feeding fish, including cod, haddock,

skate and lesser spotted catshark (dog fish). There are also numerous records of fish predation on thalassinidean mud shrimps such as *Calocaris macandreae* which has been found in the stomachs of cod and haddock. *Nephrops norvegicus* is carnivorous, feeding on brittle stars, polychaetes and other crustaceans such as *Calocaris macandreae*.
- The bodies of shrimps can offer a substratum for colonization. The ctenostome bryozoan *Triticella flava* grows a dense 'furry' covering on the antennae, mouthparts and legs of *Calocaris macandreae* (Hughes, 1998(b)), whilst the mouthparts of *Nephrops norvegicus* harbour a small commensal sessile animal, the newly described *Symbion pandora* (Conway Morris, 1995).

Seasonal and longer term change

- *Amphiura chiajei* is a long lived species. Particular cohorts (resultant of a dense and successful larval settlement) may dominate an area for over 10 years and is unlikely to show any significant regular seasonal change in abundance or biomass. However, populations of *Amphiura chiajei* seem to be periodically affected by winter cold. Mean densities of *Amphiura chiajei* in Killary Harbour, west coast of Ireland, decreased following months with the lowest recorded bottom temperatures, 4°C and 6°C, for February 1986 and January 1987 respectively. Intolerance of the acute change and depressed temperatures on the part of some older individuals probably led to their demise (Munday & Keegan, 1992).
- There are daily patterns of activity in some species. For example, in shallower water, *Nephrops norvegicus* usually remain within their burrows by day and emerge at dusk to forage during the night. The animals return to their burrows around sunrise. However, in deeper water (> 100 m) this activity rhythm is reversed, and the animals are more active by day.
- The distribution of *Nephrops norvegicus* shows some seasonality. In Loch Sween, *Nephrops* burrows were aggregated in groups during the late summer, which then broke up into a random distribution during the winter (Tuck *et al.*, 1994). Such aggregations may result when burrow complexes formed when juvenile animals settle in pre-existing adult systems, and later extend their own burrows into other areas.

Habitat structure and complexity

- The biotope has very little surface structural complexity as most species are infaunal, however, the bioturbating megafauna can create considerable structural complexity below the surface, relative to sediments that lack such animals. A low-energy hydrodynamic regime is a prerequisite for the existence of the fine sedimentary substrata about which some fauna are highly selective. For instance, *Amphiura chiajei* occurs in greatest density in habitats with a silt/clay content of 80-90% in association with an organic carbon content of 5-7%, whilst *Calocaris macandreae* only occurs in areas where silt/clay content is greater than 20%, highest densities occur where silt/clay content greater than 60% (Buchanan, 1963).
- Burrows and mounds created by burrowing megafauna may be a conspicuous feature of the sediment surface with arm tips of *Amphiura chiajei* stretching out over the surface but these are not likely to provide a significant habitat for other fauna. However, the bodies of shrimps can offer a substratum for colonization (see ecological relationships).
- Most species living within the sediment are restricted to the area above the anoxic layer, the depth of which will vary depending upon sediment particle size and organic content. Some structural complexity is provided by the burrows of macrofauna. *Brissopsis lyrifera*

maintains a respiratory funnel to the surface, whilst the burrows of *Calocaris macandreae* and *Nephrops norvegicus* are more complex. *Calocaris macandreae* constructs a system of U-shaped tunnels which may reach a depth of 21 cm. Burrows of *Nephrops norvegicus* may be very large, with tunnels over a metre in length and up to 10 cm in diameter, whilst simple burrows consist of a straight or T-shaped tunnel descending at a shallow angle and penetrating the sediment to a depth of between 20-30 cm. Burrows and the bioturbatory activity that creates them allows a much larger volume of sediment to become oxygenated, enhancing the survival and diversity of a considerable variety of smaller infaunal species (Pearson & Rosenberg, 1978).
- Deposit feeders, sort and process sediment particles and may result in destabilization of the sediment, which inhibits survival of suspension feeders. This can result in a change in the vertical distribution of particles in the sediment that may facilitate vertical stratification of some species with particle size preferences. Vertical stratification of species according to sediment particle size has been observed in some soft-sediment habitats (Petersen, 1977).

Productivity

Macroalgae are absent from CMU.BriAchi and consequently productivity is mostly secondary derived from detritus and organic material, although shallower sites may develop an extensive growth of benthic diatoms in the summer (David Hughes, pers. comm.).
Allochthonous organic material is derived from anthropogenic activity (e.g. sewerage) and natural sources (e.g. plankton, detritus). Autochthonous organic material is formed by benthic microalgae (microphytobenthos e.g. diatoms and euglenoids) and heterotrophic micro-organism production. Organic material is degraded by micro-organisms and the nutrients recycled. The high surface area of fine particles provides surface for the microflora.
Buchanan & Warwick (1974) obtained an estimate of the benthic macrofaunal production in the offshore mud off the Northumberland coast between 1971 - 1972. Eighteen species accounted for 90% of all animals, twelve being polychaetes. Although *Calocaris macandreae* was the single biomass dominant, polychaetes were responsible for the bulk of the biomass overall. The biomass averaged 3.98 g m▯, and was slightly lower in winter (3.4 - 3.8 g m▯) than summer (4.2 - 4.5 g m▯). Larger species with individual weights over 100 mg only occurred sporadically in small numbers, and accounted for 22% of the total biomass. In order of production they were: *Ammotrypane aulogaster*, *Heteromastus filiformis*, *Spiophanes kroyeri*, *Glycera rouxi*, *Calocaris macandreae*, *Abra nitida*, *Lumbrineris fragilis* and *Chaetozone setosa*. Their combined annual production was estimated to be 1432 mg m▯.
Of the species characteristic of the CMU.BriAchi biotope, *Brissopsis lyrifera* and *Calocaris macandreae* were the only significant producers, 108 mg m▯ /yr. and 142 mg m▯ /yr. respectively. The population of *Amphiura chiajei* in this study had been in decline, between 1961 and 1963 *Amphiura chiajei* density was 12-15 individuals per m▯, in 1971 only 2 individuals per m▯ were recorded. Owing to the species low productivity in this instance the authors discounted *Amphiura chiajei* from their estimates. However, the arms of *Amphiura chiajei* are an important food source for demersal fish and *Nephrops norvegicus* providing significant energy transfer to higher trophic levels. Densities of ca 700 *Amphiura chiajei* per m▯ were reported by Keegan & Mercer (1986) in Killary Harbour, Ireland, so the species is likely to be a significant producer in other instances. The estimated total production for the macrofauna was 1738 mg m▯ per annum.

Recruitment processes

- In *Brissopsis lyrifera* the sexes are separate and fertilization external, with the development of a pelagic larva (Fish & Fish, 1996). The fact that *Brissopsis lyrifera* is the only heart urchin likely to be found in muddy sediments indicates that the larvae are highly selective, and as *Brissopsis lyrifera* is a burrower the larval phase is the main dispersive mechanism of the urchin. Echinoderm larvae generally undergo a complicated and protracted metamorphosis. For instance, the larvae of other echinoderms, *Echinocardium cordatum* and *Echinus esculentus* remain in the plankton for 40 and 46-60 days respectively (Kashenko, 1994; MacBride, 1914). Thus the larvae of *Brissopsis lyrifera* probably remain in the plankton for a sufficient length of time to disperse from the location of spawning, or to repopulate an area (Nichols, 1969). However, it is likely that the low-energy hydrodynamic regime of the biotope serves to maintain the benthic population, as larvae are retained and settle back into the parent population. From his observations made off the Northumbrian coast, Buchanan (1967) describes *Brissopsis lyrifera* as a highly productive, fast growing but short lived species. It becomes sexually mature at around 4 years (test length > 60 mm), spawns in late summer / autumn and dies shortly afterwards. Specimens have not been observed to survive and breed for a second time.

- *Amphiura chiajei* reaches sexual maturity after four years and there is a seasonal cycle in gonad development. Spawning occurs between late summer and middle autumn (Fenaux, 1970). In the laboratory, Fenaux (1970) observed a complete larval metamorphosis to take only 8 days at 18°C. It is not clear whether this is representative of field conditions, at cooler temperatures metamorphosis may take longer, but such an apparently short planktonic existence would limit the species powers of dispersal. Despite spawning annually, successful recruitment tends to be sporadic. A heavy and successful settlement of *Amphiura chiajei* can dominate an area for over 10 years. The population of *Amphiura chiajei*that Buchanan (1964) sampled off the Northumbrian coast showed no evidence of recruitment between 1958 and 1964, despite spawning annually. In such long-lived, adult dominated populations in apparently stable areas, Künitzer (1989) suggested that the survival of recruits was low owing to competition with established adults, which as non-selective surface deposit feeders may take their own newly settled juveniles (0.33 mm disc diameter) as a food item. Where established adult populations have become diminished, successful recruitment has been recorded (Munday & Keegan, 1992).
- Female *Nephrops norvegicus* attain sexual maturity at 2.5-3 years of age at a carapace length of 22 mm (Howard, 1989; Bailey *et al*., 1986). Males become mature after 3 years at a carapace length of 25 mm. In Scottish waters the eggs are spawned and fertilized between August and November and carried by the females until the larvae hatch between April and August. The larvae spend about 50 days in the plankton before settlement. The juveniles appear to preferentially take up residence in existing adult burrows, constructing their burrows as an extension of these (Tuck *et al*., 1994).
- *Calocaris macandreae* is a protandrous hermaphrodite (initially male, becoming female in later life) producing eggs between January and February that hatch between September and October. Approximately 100 eggs are produced in each batch and the large larvae have no free-swimming phase before settlement. Individual *Calocaris macandreae* are very long-lived (9-10 years) and slow growing. It does not mature until five years of age, and only produces two or three batches of eggs in a lifetime. Owing to this life history pattern populations tend to be very stable in number over a 10 year period (Buchanan, 1963; 1974).

Time for community to reach maturity

Limited evidence concerning the community development of this biotope was found. The burrowing megafauna that characterize the biotope vary in their reproductive strategies and longevity. *Brissopsis lyrifera* is short lived (4 years) but fecund and shows clear evidence of successful and consecutive annual recruitment (Buchanan, 1967). Individuals become sexually mature in their forth year. *Amphiura chiajei* is longer lived than *Brissopsis lyrifera* and reaches sexual maturity in its forth year, thus the population structure of these species will not reach maturity for at least this length of time. Once established a cohort of *Amphiura chiajei* can dominate a population, even inhibiting its own consecutive recruitment, for up to 10 years. Time to reach sexual maturity is longer in *Nephrops norvegicus*, about 2.5 - 3 years and for the very long-lived *Calocaris macandreae* individuals off the coast of Northumberland did not become sexually mature until five years of age, and produced only two or three batches of eggs in their lifetime (Buchanan, 1963; 1974). In the biotope, polychaetes account for the vast proportion of the biomass, and these are likely to reproduce annually, be shorter lived and reach maturity much more rapidly. Most of the characterizing species reproduce regularly but recruitment is often sporadic owing to interference competition with established adults of the same and other species.

Owing to the fact that the characterizing species take between 3 and 5 years to reach sexual maturity, it is likely that the time for the overall community to reach a fully diverse state will also be several years. It is likely that the low-energy hydrodynamic regime is an important factor in the maintenance of stable benthic populations in this biotope, as larvae are retained in the vicinity of the parent population.

Additional information

None

Preferences & Distribution

Habitat preferences

Depth Range	20-30 m, 30-50 m, 50-100 m
Water clarity preferences	
Limiting Nutrients	No information found
Salinity preferences	Full (30-40 psu)
Physiographic preferences	
Biological zone preferences	Circalittoral
Substratum/habitat preferences	Mud, Sediments (soft)
Tidal strength preferences	Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Moderately exposed, Sheltered, Very sheltered
Other preferences	High silt/clay sediment fraction.

Additional Information

There is some doubt over records from the south coast. Holme (1961, 1966) inferred localized, usually inshore, occurrence of this community but with very few locations identified.

Species composition

Species found especially in this biotope

Rare or scarce species associated with this biotope

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Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMu.CFiMu.BlyrAchi occurs in silty mud in deep offshore, or shallower stable nearshore, moderately exposed, sheltered and very sheltered conditions with weak or very weak tidal streams (Connor *et al*., 2004). This low energy biotope is characterized by the presence of urchin *Brissopsis lyrifera* and brittlestar *Amphiura chiajei*. Both these species are associated with muddy substrata. Furthermore, as bioturbators, densities of *Brissopsis lyrifera* and *Amphiura chiajei* have been shown to have significant impacts on nutrient balance in the biotope (Olsgard *et al*., 2008). *Brissopsis lyrifera* and *Amphiura chiajei* are therefore considered the key characterizing and key functional species of SS.SMu.CFiMu.BlyrAchi, and the sensitivity assessments focus on these two species.

The remaining biological community is represented by infaunal species that are similar to those found in SS.SMu.CFiMu.SpnMeg and include a number of polychaetes, small bivalves, and low numbers of the seapen *Virgularia mirabilis*. In addition, in certain areas of the UK such as the northern Irish Sea, this community may also contain lobster *Nephrops norvegicus* and can consequently be the focus for fishing activity (Mackie *et al*., 1995). The potential implications of this activity on the biotope's community are included in this assessment, where relevant.

Resilience and recovery rates of habitat

The burrowing megafauna that characterize the biotope vary in their reproductive strategies and longevity. *Brissopsis lyrifera* is short lived (4 years) but is fecund and has shown evidence of successful and consecutive annual recruitment (Buchanan, 1967). Adult *Brissopsis lyrifera* are burrowers, so the larval phase is the main dispersive mechanism of the urchin. Echinoderm larvae undergo a complicated and protracted metamorphosis in the plankton. For instance, the larvae of other echinoderms, *Echinocardium cordatum* and *Echinus esculentus* remain in the plankton for 40 and 46-60 days, respectively (Kashenko, 1994; MacBride, 1914). Thus, the larvae of *Brissopsis lyrifera* probably remain in the plankton for sufficient time to be swept away from their spawning ground to new areas or to re-populate disturbed areas (Nichols, 1969). Whilst, recolonization is likely to occur rapidly, the new population will not reach reproductive maturity for about four years (Buchanan, 1967).

Amphiura chiajei is longer lived than *Brissopsis lyrifera* and reaches sexual maturity in its fourth year, with sporadic recruitment, slow growth rate, and late maturity and longevity (Buchanan, 1964). Once established, a cohort of *Amphiura chiajei* can dominate a population, even inhibiting its own consecutive recruitment, for up to 10 years. Munday & Keegan (1992) suggested, based on observations in Killary Harbour, Ireland, that individuals of *Amphiura chiajei* attained an age of 10 years, an estimate that was consistent with that reported for populations of *Amphiura chiajei* living off the Northumbrian coast (Buchanan, 1964). In most species of ophiuroids the sexes are separate and fertilization external, leading to the development of a pelagic larva, the ophiopluteus (Fish & Fish, 1996), with individuals reaching reproductive maturity after four years. In *Amphiura chiajei* there is a seasonal cycle in gonad development and spawning occurs over the period from the end of summer until the middle of autumn (Fenaux, 1970). In the laboratory, Fenaux (1970) observed a complete larval metamorphosis through to the formation of a young ophiuroid within 8 days at temperature of 18-20°C. Fenaux (1970) suggested that for eggs laid at the end of summer and at the beginning of autumn in which the water temperature exceeds 20°C, the pelagic life is probably shorter. With such a short life in the plankton, the dispersal potential is likely to be rather limited in comparison to other echinoderms. In long-lived, dense, adult-dominated populations in apparently very stable areas, Künitzer (1989) suggested that the survival of recruits was low owing to competition with established adults, which, as a non-selective surface deposit feeders, may take their own juveniles as a food item at the earliest settlement stage (0.33 mm disc diameter). In contrast, in areas which experience periodic instability, such as the Bay of Concarneau, France, populations of *Amphiura* species are prevented from reaching carrying capacity owing to periodic reduction of the population density (Bourgoin & Goillou, 1988). Likewise, Munday & Keegan (1992) only recorded a successful recruitment of juveniles following the significant demise of adults after depressed winter temperatures in Killary Harbour, Ireland. Therefore, it appears that after removal of all or most of the population by a pressure, recovery is possible through larval settlement.

In the Irish Sea, *Nephrops norvegicus* individuals are not thought to live more than 8 or 9 years and sexually mature at about 2.5 - 3 years. However, in deeper waters such as the Porcupine Bank they may survive over 15 years (Marine Institute, 2001). *Nephrops norvegicus* has a pelagic larval stage lasting up to 50 days (Johnson *et al*., 2013; Powell & Eriksson, 2013). Local populations of *Nephrops norvegicus* may vary considerably in density, size and growth rate (Tuck *et al*., 1997) with fecundity also varying geographically (Eiriksson, 1970; Tuck *et al*., 1997). The percentage of eggs lost during development can range from 32 - 51 % with larval mortalities as high as 87% (Garrod & Harding, 1980) which could reduce recovery rates. As a result *Nephrops norvegicus* do not produce large numbers of offspring. Potential recruitment from other populations of *Nephrops norvegicus* is low as larvae do not have a high dispersal potential and adults show no evidence of migration (Marine Institute, 2001).

Slender sea pen *Virgularia mirabilis* is up to 60 cm tall and half of the total length is buried in the substratum in which it lives (Wood, 2005), living upright with their stalks thrust into a mucus-lined burrow into which the whole colony can withdraw when disturbed. It is likely that the life cycle of *Virgularia mirabilis* is similar to that of other sea pens described in the literature (Edwards & Moore, 2009) which suggest patchy recruitment, slow growth and long lifespan (Hughes, 1998a).

Polychaetes in this biotope, including *Glycera* spp. and *Nephtys* spp. are infaunal and likely to vary in their recovery potentials. The genus *Glycera* has a relatively long lifespan of five years. *Nephtys* is a relatively long-lived polychaete genus with a lifespan of six to possibly as much as nine years (MES, 2010). The genus has a relatively high reproductive capacity and widespread dispersion during the lengthy larval phase. It is therefore likely to have a high recovery potential following disturbance (MES, 2010).

Resilience assessment: The burrowing megafauna that characterize the biotope vary in their reproductive strategies and longevity. Biss*opsis lyrifera* is short lived (4 years) but is fecund and has shown clear evidence of successful and consecutive annual recruitment (Buchanan, 1967). Individuals become sexually mature in their fourth year. *Amphiura chiajei* is longer lived than *Brissopsis lyrifera* and reaches sexual maturity in its fourth year, thus the population structure of these species will not reach maturity for at least this length of time. Once established, a cohort of *Amphiura chiajei* can dominate a population, even inhibiting its own consecutive recruitment, for up to 10 years. Time to reach sexual maturity is longer in *Nephrops norvegicus*, about 2.5 - 3 years. In the biotope, polychaetes account for the vast proportion of the biomass, and these are likely to reproduce annually, be shorter lived and reach maturity much more rapidly (MES, 2010).

Most of the characterizing species reproduce regularly but recruitment is often sporadic owing to interference competition with established adults of the same and other species. However, owing to the fact that the characterizing species take between 3 and 5 years to reach sexual maturity, it is likely that the time for the overall community to reach a fully diverse state will also be several years. It is likely that the low-energy hydrodynamic regime is an important factor in the maintenance of stable benthic populations in this biotope, as larvae are retained in the vicinity of the parent population. Where the biotope has **Medium** resistance to a disturbance, resilience is likely to be **High** given that the majority of the key species of the biotope can maintain the character to the biotope and recruit within the first two years after disturbance. However, when a significant proportion of the population is lost (resistance **Low** or **None**), the individual key species may recolonize the area within five years, with the biotope taking longer to return to original species diversity, so abundance and resilience is likely to be **Medium** (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)	High Q: High A: High C: High	High Q: High A: Medium C: High	Not sensitive Q: High A: Medium C: High

The species that occur in this biotope are widely distributed and found both north and south of the British Isles (Hayward & Ryland, 1995b). In shallower locations e.g. sea lochs, sedimentary biotopes typically experience seasonal changes in temperature of about 10°C (5-15°C) (Hughes, 1998b) and it is likely that the SS.SMu.CFiMu.BlyrAchi community would be resistant of an acute temperature increase. For most offshore burrowing species, temperature changes in the water column are likely to be buffered by the insulation offered by the substratum and the depth of overlying water. A temperature increase may enhance growth and fecundity in brittlestars. Muus (1981) showed that juvenile *Amphiura filiformis* are capable of much higher growth rates in experiments with temperatures between 12 and 17°C (unlimited food supply). Juvenile disc diameter increased from 0.5 to 3.0 mm in 28 weeks under these conditions compared to over 2 years in the North Sea. Mean summer temperatures of 14°C and an apparent abundant food supply may also have accounted for the early rapid growth of *Amphiura chiajei* in Killary Harbour (Munday & Keegan, 1992). In *Brissopsis lyrifera*, processes such as mobility, sediment turnover and re-mineralization may increase (K. Hollertz, pers. comm., Hollertz & Duchêne, 2001). Hollertz & Duchêne (2001) found that in *Brissopsis lyrifera*, the amount of re-worked sediment due to burrowing almost doubled from 14 to 22 ml/l sediment per hour when the temperature increased from 7 to 13°C. This temperature increase also saw the amount of ingested sediment increase from 0.02 to 0.08 g dry sediment per hour. However, increased water temperature may enhance microbial decomposition within the substratum and promote de-oxygenation, to which *Brissopsis lyrifera* is not resistant.

Sensitivity assessment: The biotope is subtidal and a low energy environment where wide and rapid variations in temperature are less common. The community is therefore less likely to be resistant of an acute increase in temperature. However, the distribution data suggest that species in this biotope are unlikely to be adversely affected by an increase in temperature at the pressure benchmark level. Furthermore, the evidence presented suggests that growth and recruitment of the characterizing species of the biotope, *Brissopsis lyrifera* and *Amphiura chiajei* may benefit from an increase in temperature at the pressure benchmark level. Resilience and resistance are therefore assessed as **High** and the biotope considered **Not Sensitive** at the pressure benchmark level.

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

The species occurring in this biotope are widely distributed and found both north and south of the British Isles (Hayward & Ryland, 1995b). In shallower locations e.g. sea lochs, sedimentary biotopes typically experience seasonal changes in temperature of about 10°C (5-15°C) (Hughes, 1998b) and it is likely that the SS.SMu.CFiMu.BlyrAchi community would be resistant of a long-term temperature decrease. For most offshore burrowing species temperature changes in the water column are likely to be buffered to some extent by the insulation offered by the substratum and the depth of overlying water. However, burrowing itself has been found to be significantly affected by temperature in *Brissopsis lyrifera*. Hollertz & Duchêne (2001) found that *Brissopsis lyrifera* re-worked almost half the amount of sediment per hour at 7°C compared to activity at 14°C. Furthermore, *Brissopsis lyrifera* maintains a continuous contact with the overlying water column through the funnel (Hollertz, 2002). Also, the biotope community seems to be periodically affected by severe winters. Mean densities of *Amphiura chiajei* in Killary Harbour, west coast of Ireland, decreased following months with the lowest recorded bottom temperatures, 4°C and 6°C, for February 1986 and January 1987, respectively. Lack of resistance of the acute change and depressed temperatures on the part of some of the older individuals probably led to their demise (Munday & Keegan, 1992). Low temperatures are also a limiting factor for breeding, which occurs in the warmest months in the UK. Temperature tolerances of *Brissopsis lyrifera* are unknown but low water temperatures have caused mass mortalities of other similar echinoderms, such as *Echinocardium cordatum*. In the severe winter of 1962-63 masses of dead *Echinocardium cordatum* were observed in regions of the North Sea and English Channel, although it was reported that living specimens were obtained easily enough by digging (Crisp, 1964).

Sensitivity assessment. Although the evidence suggests possible effects on metabolism and recruitment for the characterizing species of this biotope caused by a decrease in temperature, their cosmopolitan distribution suggests that *Brissopsis lyrifera* and *Amphiura chiajei* are likely to be able to resist a decrease in temperature at the benchmark level. Resistance and resilience are therefore assessed as **High** and the biotope considered **Not Sensitive** to a decrease in temperature at the benchmark level.

Salinity increase (local)	Low Q: Low A: Low C: Medium	Medium Q: High A: Medium C: High	Medium Q: Low A: Low C: Low

The biotope SS.SMu.CFiMu.BlyrAchi is found within fully marine subtidal locations and it is highly unlikely that the biotope would experience conditions of hypersalinity. However, it is likely that key components of the biotope community would not be resistant of an increase in salinity. For instance, echinoderms such as *Brissopsis lyrifera* and *Amphiura chiajei* are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987). Echinoderm larvae are particularly sensitive to reduced or increased salinity (Stickle & Diehl, 1987).

Sensitivity assessment. There is little direct evidence of the effects of hypersaline conditions on the characterizing species of this biotope, *Brissopsis lyrifera* and *Amphiura chiajei*. However, echinoderms are generally considered to be stenohaline (Stickle & Diehl, 1987; Russell, 2013). Therefore, an increase in salinity to >40 psu is likely to result in mortality and resistance is assessed as **Low** but with low confidence. Resilience is probably **Medium** so that sensitivity is therefore assessed as **Medium**.

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

The biotope SS.SMu.CFiMu.BlyrAchi is found within fully marine subtidal locations and it is highly unlikely that it would experience conditions of hyposalinity, except from effluent. However, it is likely that key members of the biotope community would not be resistant of a decrease in salinity. For instance, echinoderms such as *Brissopsis lyrifera* and *Amphiura chiajei* are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987). Pagett (1981) examined the resistance of *Amphiura chiajei* to brackish water (0.5-30 psu) in specimens taken from Loch Etive, Scotland. Loch Etive is a sea loch subject to periods of reduced salinities owing to heavy rain and freshwater runoff. The author suggested that localised physiological adaption to reduced or variable salinities may occur in nearshore areas subject to freshwater runoffs. *Amphiura chiajei* taken from an area of 24 psu had an LD50 of > 21 days for a 70% dilution (17 psu) and an LD50 of 8.5 days for a 50% dilution (12 psu). In comparison, specimens taken from an area with salinity 28.9 psu, had an LD50 of >12.5 days for a 70% dilution (20 psu) and an LD50 of 6 days for a 50% dilution (14 psu). As *Amphiura chiajei* is mobile and burrows it may be able to avoid changes in salinity outside its preference, e.g. burrowing may help *Amphiura chiajei* to withstand depressed salinities owing to the 'buffering' effect of the substratum. A review by Russell (2013) reported that *Amphiura chiajei* tolerated salinities of 14.8‰, 20.7‰ and 18‰ in Portugal, Scotland and the Black Sea, respectively. However, no information concerning the specific tolerance of *Brissopsis lyrifera* to a decrease in salinity was found but burrowing in the muddy sediment may offer some protection to this species.

Sensitivity assessment. Populations that occur in sheltered nearshore situations, such as sea lochs, which periodically receive inputs of freshwater are unlikely to experience the reduced salinities recorded at the surface. However, this circalittoral biotope is less likely to experience variable salinities, and resident species, therefore, less likely to adapt to variation in salinity, as suggested by the results given by Pagett (1981). Therefore, resistance to a decrease in salinity from full to reduced (18-30 psu) is assessed as **Low** (loss of 25-75% of individuals). Resilience is assessed as **Medium** (2-10 years) and the biotope is considered to have **Medium** sensitivity at the benchmark level.

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

The presence of the biotope is determined by a low energy hydrodynamic regime facilitating the deposition of cohesive fine silts and clays. The substratum is likely to remain unchanged because the smooth compacted fine sediments require very high shear stresses to be eroded. However, the settlement of the planktonic larvae of these key species may be inhibited with an increase in water flow owing to re-suspension along with particulate matter. Consequently, the viability of the population may be reduced. Furthermore, the deposit feeding community may experience a reduction in food availability owing to reduced deposition of organic matter. The community is not likely to be directly vulnerable to a decrease in water flow rate but sediments may become muddier owing to increased settlement of particulate matter. However, as deposit feeders are the dominant trophic group such additional material may be utilized as a food resource and the community may benefit indirectly.

Brissopsis lyrifera is characteristic of offshore muddy sedimentary habitats exposed to only weak or very weak currents (Budd, 2004). *Amphiura chiajei* shows no clear response to directional bottom currents or an increase in water current rate (Buchanan, 1964). In laboratory conditions, *Amphiura chiajei* maintained a position within the sediment with its arms stretched out across the sediment until 0.3 m/s, when the arms streamed out in the direction of the water current (Buchanan, 1964). Increases in water flow rates could mean the brittlestars would withdraw arms from the current and cease feeding.

Sensitivity assessment. The assessment is based largely on the Hjulström-Sundborg diagram (Sundborg, 1956). This relates current velocity to deposition, erosion and transport. While this model has largely been superseded in by more recent models that take into account other factors such as shear stress and water depth, these newer models are more complex, site specific and do not relate sediment transport to water velocity. The curve is therefore used to assess generally the potential effects of changes in water velocity but it should be recognized that a number of other factors will mediate effects. Both characterizing species of this biotope are normally associated with weak and very weak tidal streams (negligible - <0.5 m/s). A decrease in water flow rate would likely result in increased siltation, potentially associated with increased deposition organic matter, which would likely indirectly benefit the characterizing species of the biotope. An increase in water flow may alter the character of the sediment of the biotope by washing away finer particle, which could potentially exclude colonization of the characterizing species of the biotope, such as *Brissopsis lyrifera*, which is associated to muddy/silty substrata. However, records indicate the biotope occurs in weak and very weak tidal streams (Connor *et al.*, 2004). This range is likely to exceed the pressure benchmark. Resistance and resilience are therefore assessed as **High** and the biotope considered **Not Sensitive** to a change in water flow at the pressure benchmark level.

Emergence regime 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

Changes in emergence are **Not Relevant** to biotopes which are restricted to fully subtidal/circalittoral conditions. The pressure benchmark is relevant only to littoral and shallow sublittoral fringe biotopes.

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

The SS.SMu.CFiMu.BlyrAchi biotope occurs offshore and in sheltered nearshore habitats where wave exposure is negligible (Connor *et al.*, 2004), so the biotope is probably not resistant to changes in wave exposure. However, as the effects of wave action are attenuated with depth, the factor is only likely to affect the biotope where it occurs at depths of less than 60 m in a strong swell or force 8 gale (Hiscock, 1983). Wave action resulting from storms may disturb the surface sediment. McIntosh (1975) reported specimens of *Amphiura chiajei* thrown on to West Sands, St. Andrews Bay after storms. Long-term increases in wave exposure is likely to cause the substratum character to be altered, as wave action would penetrate the substratum to a greater depth, and become outside the habitat preference of the species. The community would no longer occur at that location. However, *Amphiura chiajei* is a burrower and may withdrawal its arms into the burrow for additional protection, but because wave action may cause displacement and stranding, it is likely to cause some mortality in shallower locations.

Brissopsis lyrifera is characteristic of offshore and stable muddy nearshore habitats, where wave exposure is negligible. Populations situated in normally sheltered stable habitats at shallower depths may experience some disturbance to the sediment surface. However, as *Brissopsis lyrifera* burrows in the sediment to a depth of 10 cm, it is unlikely that turnover and displacement would occur to an extent where the population is significantly reduced.

Sensitivity assessment. A decrease in wave exposure is not relevant because this biotope is characterized as a low energy environment. An increase in wave exposure is likely to adversely affect the characterizing species in this biotope, limiting or removing the shallower proportion of the community, and potentially modifying sediment and therefore habitat preferences in the longer-term. However, records indicate the biotope occurs in a range of wave exposures (Connor *et al*., 2004). This range is likely to exceed the pressure benchmark. Additionally the depth at which the biotope occurs is likely to provide some protection to changes in wave height at the pressure benchmark level. Resistance and resilience are therefore assessed as **High** and the biotope considered **Not Sensitive** to a change in nearshore significant wave height >3% but <5%.

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.

Information concerning the effects of heavy metals on echinoderms is limited and no information specific to *Brissopsis lyrifera* and *Amphiura chiajei* was found. In Norwegian fjords, Rygg (1985) found a relationship between species diversity in benthic fauna communities and sediment concentrations of heavy metals Cu, Pb and Zn. Cu in particular showed a strong negative correlation and the author suggested a cause-effect relationship. Those species not present at sites where Cu concentrations were greater than ten times the background level, such as *Amphiura filiformis* and the bivalve *Nucula sulcata* (also found in SS.SMu.CFiMu.BlyrAchi), were assessed as non-resistant species. Resistant species were all polychaete worms. Polychaete worms are the dominant component of the biomass in SS.SMu.CFiMu.BlyrAchi and thus may not be as sensitive as the characterizing species. Crompton (1997) reports that the concentrations above which mortality of crustaceans can occur is 0.01-0.1 mg/l for mercury, copper and cadmium, 0.1-1.0 mg/l for zinc, arsenic and nickel and 10 mg/l for lead and chromium. Some burrowing crustaceans, brittlestars and bivalves may disappear from the biotope and lead to an increasing dominance of polychaetes. Bryan (1984) suggested that metal-contaminated sediments can exert a toxic effect on burrowing bivalves and echinoderms, especially at larval stages, and that polychaetes were fairly resistant. Adult echinoderms, such as *Ophiothrix fragilis* are known to be efficient concentrators of heavy metals including those that are biologically active and toxic (Hutchins *et al*., 1996). However, there is no information available regarding the effects of this bioaccumulation. More recent studies by Deheyn & Latz (2006) at the Bay of San Diego found that heavy metal accumulation in brittlestars occurs both through dissolved metals as well as through diet, to the arms and disc, respectively. Similarly, Sbaihat *et al.* (2013) measured concentrations of heavy metals (Cu, Ni, Cd, Co, Cr and Pb) in the body of *Ophiocoma scolopendrina* collected from the Gulf of Aqaba, and found that most concentration was found in the central disc rather than arms and no simple correlations could be found between contaminant and body length. It is logical to suppose that brittlestar beds would be adversely affected by major pollution incidents such as oil spills, or by continuous exposure to toxic metals, pesticides, or the antiparasite chemicals used in cage aquaculture. So far, however, there are no field observations of epifaunal brittlestar beds being damaged by any of these forms of pollution, and there seems to be no evidence of the toxicity effects of heavy metal accumulation on brittlestars.

The evidence presented suggests that the characterizing species in this biotope are likely to bio-accumulate heavy metals which could result in changes in the faunal composition of the community and decrease overall species diversity.

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.

Chronic sub-lethal effects were detected around the Beryl oil platform in the North Sea where the hydrocarbon content of the sediment was very low (<3 ppm total hydrocarbons in sediment), and *Amphiura chiajei* was excluded from areas nearer the platform with higher sediment hydrocarbon content (> 10 ppm) (Newton & McKenzie, 1998). *Amphiura chiajei* is also host to symbiotic sub-cuticular bacteria (Kelly & McKenzie, 1995). After exposure to hydrocarbons, loadings of such bacteria were reduced indicating a possible sub-lethal stress to the host (Newton & McKenzie, 1995). Furthermore, *Brissopsis lyrifera* has a continuous water flow over the test so the exposure route through the epidermis may also be important (K. Hollertz, pers. comm., Hollertz, 2002). However, as a burrower and deposit feeder, ingestion of contaminated sediments is likely to be a more important route of exposure. A range of effects (mortalities, feeding/growth inhibition and embryological abnormalities) have been reported for other echinoderms following hydrocarbon exposure (reviewed by Suchanek, 1993).

Untreated oil (e.g. from oil spills) is not a risk, since it is concentrated mainly at the surface, and circalittoral biotopes are likely to be protected by their depth. If oil is treated by dispersant, the resulting emulsion will penetrate down the water column, especially under the influence of turbulence (Hartnoll, 1998).

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.

Effects caused by synthetic chemicals have been reported for some of the individual species in the SS.SMu.CFiMu.BlyrAchi biotope. Dahllöf *et al*. (1999) studied the long-term effects of tri-n-butyl-tin (TBT) on the function of a marine sediment system. TBT spiked sediment was added to a sediment that already had a TBT background level of approximately 27 ng/g (83 pmol TBT per g) and contained the following fauna: *Amphiura* spp., *Brissopsis lyrifera* and several species of polychaete. Within two days of treatment with a TBT concentration above 13.7 μmol/m□ all species except the polychaetes had crept up to the surface and after six weeks these fauna had started to decay. Thus, contamination from TBT is likely to result in the death of some not-resistant species such as brittlestars and heart urchins. *Amphiura chiajei* is also known to bioaccumulate PCBs, although direct effects of synthetic chemicals on this species are unknown (Gunnarsson & Skold, 1999). However, Walsh *et al.* (1986) observed inhibition of arm regeneration in another brittlestar, *Ophioderma brevispina*, following exposure to TBT at levels between 10 ng/l and 100 ng/l. Loizeau & Menesguen (1993), found that 8-15% of the PCB burden in dab, *Limanda limanda*, from the Bay of Seine could be explained by ophiuroid consumption. Thus, *Amphiura* communities may play an important role in the accumulation, re-mobilization and transfer of PCBs and other sediment associated contamination to higher trophic levels.

Detergents used to disperse oil from the *Torrey Canyon* oil spill caused mass mortalities of a similar species, *Echinocardium cordatum* (Smith, 1968). Sea-urchins, especially the eggs and larvae are used for toxicity testing and environmental monitoring (reviewed by Dinnel *et al*., 1988). It is likely therefore, that *Brissopsis lyrifera* and its larvae are not resistant to synthetic compound contamination.

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

There is insufficient information on the resistance of *Amphiura chiajei* to radionuclides, although adult echinoderms, such as *Ophiothrix fragilis*, are known to be efficient concentrators of radionuclides (Hutchins *et al*., 1996). However, no information concerning the effects of such bioaccumulation was found.

Carvalho (2011) determined the concentrations of ^{210}Po and ^{210}Pb in marine organisms from the seashore to abyssal depths, as these two radioactive elements tends to be higher in the marine environment. The author's results showed that concentrations varied greatly, even between organisms of the same biota, mainly related with the trophic levels occupied by the species, suggesting that the more levels between a species and the bottom of the food chain, the more likely that the concentrations of radioactive elements were likely to be diluted. This may have great implications for the detritus feeders that characterize this biotope. There was no information available about the effect of this bioaccumulation.

Sensitivity assessment: Although species in this biotope are likely to bio-accumulate radionuclides with potential impacts on the biological community, no information concerning the effects of such bioaccumulation was found. Therefore, there is insufficient evidence to assess this pressure against the benchmark.

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

This pressure is **Not assessed**.

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

Infaunal burrowers in the community live in close association with hypoxic and even anoxic muddy substrata. In experiments, *Amphiura chiajei* exposed to decreasing oxygen levels only left its protected position in the sediment when oxygen levels fell below 0.54 mg/l (Rosenberg *et al.*, 1991). This escape response increases its risk to predators. Mass mortality in a superficially similar species of ophiuroid, *Amphiura filiformis* from the south-east Kattegat was observed during severe hypoxic events (< 0.7 mg/l), while the abundance of *Amphiura chiajei* remained unchanged at the same site and time (Rosenberg & Loo, 1988). Nilsson (1999) maintained specimens of *Amphiura chiajei* in hypoxic conditions (1.8-2.2 mg/O_2/l for eight weeks and recorded no deaths or witnessed specimens escaping to the surface.

Brissopsis lyrifera was reported to be not resistant of hypoxia (Diaz & Rosenberg, 1995). It was reported to leave its position within the substratum and lie exposed on the sediment surface in bottom waters with an oxygen concentration of 1 ml/O_2/l (Baden *et al.*, 1990). At a bottom water oxygen concentration of ca. 1 ml/l (15% saturation) in the Kattegat, Baden *et al.* (1990) caught no fish, but 200-400 kg per hour of benthic invertebrates that included the echinoderms *Brissopsis lyrifera*. Similar mass migration of benthic infauna (including *Brissopsis lyrifera*) to the sediment surface was recorded during trawling in the North Sea with low values of oxygen (ca 2 ml/l) (Dyer *et al.*, 1983). Hollertz (2002) reported that *Brissopsis lyrifera* could tolerate ca 4 ml/l (ca 5.6 mg/l) for at least 15 hours in the laboratory and that the animals recovered quickly. In the Gullmarsfjord (where *Brissopsis lyrifera* is recorded; Brattström, 1946; Vasseur & Carlsen, 1949), a 1980/1981 hypoxia event, ca 0.2 ml/l, eliminated all the macrobenthic fauna below 115 m depth. The recovery sequence was slow and communities were not re-established eighteen months after the collapse (Josefson & Widbom, 1988).

Sensitivity assessment: The evidence presented suggests that exposure to dissolved oxygen concentration of less than or equal to 2 mg/l may result in some mortality of the key species in this biotope. Resistance is therefore assessed as **Low**, resilience and **Medium** and the biotope is judged as having **Medium** sensitivity to de-oxygenation at the pressure benchmark level.

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

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 de-oxygenation 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 sea bed may also be enhanced. *Amphiura chiajei* has been reported as highly intolerant of changes in nutrients, and that *Brissopsis lyrifera* may be favoured by Hiscock *et al.* (2005a). Bioturbators such as the characterizing species of this biotope are likely to be able to utilize extra nutrients that may end up in the biotope as a result of nutrient enrichment as shown by the result of Olsgard *et al.* (2008) who highlighted the importance of macrofauna as facilitators of nutrient flux in soft-sediments. The authors suggested that *Brissopsis lyrifera* plays an important role in nutrient cycling and ecosystem functioning. Equally, Widdicombe *et al.* (2013) suggested that the presence of urchins preferentially stimulates nitrification (a process by which nutrients are recycled in the sediment), increasing the production of nitrite and nitrate within the sediment and therefore reducing the gradient in nutrient concentrations that exists between the overlying water and sediment porewaters.

Sensitivity assessment: The overall species diversity in this biotope is likely to decline given the varying abilities of the species occurring here to nutrient enrichment (Hiscock *et al.*, 2005a). The community, and hence the biotope, may change to one dominated by nutrient enrichment resistant species, in particular polychaete worms such as *Capitella capitata*. However, these changes generally refer to gross nutrient enrichment. A decrease in nutrient availability may result in impaired growth and fecundity although species diversity is not likely to be affected significantly. Nevertheless, the biotope is considered to be **Not Sensitive** at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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

Organic enrichment is likely to promote pelagic productivity and increase the amount of organic matter reaching the sea bed. Nilsson (1999) reported a positive response by *Amphiura chiajei* to increased organic enrichment (27 and 55 gC/m▯, applied four times over eight weeks) demonstrated by an increase in arm tip regeneration rate. Nilsson (1999) also found that *Amphiura chiajei* was able to utilize an increased input of organic matter for growth in conjunction with moderate hypoxia. In the Skagerrak in the North Sea, Josefson (1990) reported a massive increase in abundance and biomass of *Amphiura* species between 1972 and 1988 attributable to organic enrichment. Sköld & Gunnarsson (1996) reported enhanced growth and gonad development in response to short-term enrichment of sediment cores containing *Amphiura chiajei* maintained in laboratory mesocosms. For benthic deposit feeders, food is suggested to be a limiting factor for body and gonad growth, at least between events of sedimentation of fresh organic matter (Hargrave, 1980; Tenore, 1988).

Brissopsis lyrifera is a non-selective deposit feeder, characteristic of muddy sediments with significant organic matter content, so an increase in the suspended matter settling out from the water column to the substratum may be used as a food resource. *Brissopsis lyrifera* has been reported to increase surface deposit feeding activity after the addition of organic matter, which resulted in an increase in growth (Hollertz *et al.*, 1998). The species is also capable of filter feeding although ventilation rates are not high enough to sustain the animal on filter feeding alone (Hollertz, 2002). However, a study by Kutti *et al.* (2008) of the effects of organic effluents from a salmon farm on a Norwegian fjord system, indicated that the threshold for increased infauna production for a benthic ecosystem at the depth of 230 m was reached at an annual flux of 300-500 g C m^2 and that continuous loadings at this magnitude over time might cause overloading of fish farm localities. *Brissopsis lyrifera* was recorded as one of the three dominating infauna species within close proximity of the farm (within 250 m). Nevertheless, eutrophication resulting from high pelagic production, in combination with thermal stratification of the water column in summer is likely to cause mortality of *Brissopsis lyrifera* indirectly, owing to the effects of hypoxia. Although hypoxia or even anoxia is likely to occur as a result of increased organic matter deposition, macrofauna, such as the characterizing species of this biotope are likely to enhance utilization of organic matter by aerobic bacteria in the sediment by bioturbation (active mixing of sediment) and bioirrigation (active flushing of solutes) (Sanz-Lázaro & Marín, 2011).

Borja *et al.* (2000) and Gittenberger & van Loon (2011) in the development of an AMBI index to assess disturbance (including organic enrichment) both assigned *Brissopsis lyrifera* to their

Ecological Group I 'species very sensitive to organic enrichment and present under unpolluted conditions'. However, for *Amphiura chiajei*, while Borja *et al.* (2000) assigned the species to Ecological Group I 'species very sensitive to organic enrichment and present under unpolluted conditions', Gittenberger & van Loon (2011) assigned the species to Ecological Group II 'species indifferent to enrichment, always present in low densities with non-significant variations with time (from initial state, to slight unbalance)'.

Sensitivity assessment. The evidence presented based on the AMBI scores conflicts and is not directly comparable with the benchmark so it is considered with caution. Bioturbators, such as the characterizing species of this biotope are likely to be able to utilize extra nutrients that may end up in the biotope as a result of organic enrichment. 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, such as those where this biotope tends to occur. In summary, some mortality of the characterizing species of this biotope is likely to occur, either as a direct result of a deposit of 100 gC/m^2 over the period of one year, or indirect result of hypoxia. Resistance is therefore assessed as **Low** (loss of 25-75%) and resilience as **Medium**. Thus, the biotope is considered to have **Medium** sensitivity to organic enrichment at the pressure benchmark level.

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 silty mud that characterizes this biotope was replaced with soft or hard rock substrata, this would represent a fundamental change to the physical character of the biotope. Additionally, the biological community that occurs and characterizes the biotope would no longer be supported. The biotope would, therefore, be lost.

Sensitivity assessment: Resistance to the pressure is considered **None**, and resilience **Very Low**. Sensitivity has been assessed as **High**.

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.CFiMu.BlyrAchi is limited to silty muds (Connor *et al.*, 2004), and particularly the characterizing species that it supports exhibit specific preferences for fine sediment substrata. *Brissopsis lyrifera* has a preference for cohesive sandy mud and silty mud (Tillin & Tyler-Walters, 2014); and *Amphiura chiajei* is found in mud and muddy sand (Budd, 2006). The remaining species that compose the biological community demonstrate higher plasticity in terms of sediment preferences. Although *Nephrops norvegicus* has been recorded across a range of substrata, creating permanent burrows will typically have specific sediment requirements which have been seen to relate to the maintenance of burrow structures, and to affect population densities, with preferences seeming to focus on sandy-muds than muds and In medium-grained mud sediments (Daly & Mathieson, 1977; Afonso-Dias, 1998).

Sensitivity assessment: The characterizing species of this biotope are associated with a narrow range of sediments types, including silty muds and muddy sands. For this biotope, a change in Folk class would mean a change from mud and sandy mud to sand or muddy sand, or to gravelly mixed sediment. The characterizing species are unlikely to be resistant of such a change in sediment type, no longer being supported, and hence lost from the biotope. The biotope is likely to be lost, so resistance is therefore assessed as **None** and resilience as **Very Low**, given the permanent character of this pressure. The biotope is considered to have **a High** sensitivity to a change in seabed type by one Folk class.

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

SS.SMu.CFiMu.BlyrAchi is highly unlikely to be resistant of substratum loss because most species are infaunal and extraction of substratum to 30 cm is likely to result in the removal of the biological community along with substrata, including the characterizing species. Newell *et al.* (1998) stated that removal of 0.5 m (50 cm) depth of sediment is likely to eliminate benthos from the affected area. *Brissopsis lyrifera* burrows to a depth of up to 10 cm; *Amphiura chiajei* lives partially buried with its disc at a depth of 6 cm. These species are not sufficiently mobile to avoid substratum removal. Although some species are mobile, e.g. *Nephrops norvegicus*, if disturbed they are likely to seek refuge within a burrow within the substratum and so are also likely to be removed. Shallow and deep disturbance can injure, kill and displace benthic organisms and, in the case of fisheries, target and non-target species can be removed from the habitat. Through these effects, fisheries can alter the biomass, production and species richness of benthic invertebrate communities (Hiddink *et al.*, 2006). Otter boards plough a groove in the seabed, which can vary from a few cm to 0.3 m deep (Jones, 1992, references therein). The trawl may remove or damage sedentary organisms and displace stones. Bobbins and chains can also leave tracks (Krost *et al.*, 1989) and remove surface sediment. The disturbance depth depends on board weight, the angle of tow and the nature of the substratum (Jones, 1992). Sediment recovery time and infilling will depend on local hydrodynamics and the substratum. Neither *Brissopsis lyrifera* or *Amphiura chiajei* are targeted for collection or harvesting, but *Nephrops norvegicus* is the target of a large commercial fishery. For example, dredging operations were shown to affect large infaunal and epifaunal species, decrease sessile polychaetes and reduce numbers of burrowing heart urchins (Eleftheriou & Robertson, 1992). In a study on the effects of otter trawling for *Nephrops norvegicus* on the benthos of locations in the Irish Sea and Scottish sea lochs, Ball *et al.* (2000a) reported a reduction in the abundance of large-bodied and fragile organisms such as *Brissopsis lyrifera* and *Amphiura chiajei* and suggested that these species are particularly unlikely to be resistant of trawling disturbance. An altered but stable community resulted, composed of fewer species and reduced faunal diversity, and primarily of small polychaetes. In a study comparing the responses of marine benthic communities within a variety of sediment types to physical disturbance, Dernie *et al.* (2003) found that mud habitats had an ‘intermediate’ recovery time (compared to clean sand communities which had the most rapid recovery rate, and muddy sand habitats had the longest recovery times).

Sensitivity assessment. Due to the nature of this pressure, it is highly likely that a large amount of the sediment would be removed along with the biological community, resulting in the removal of the biotope. Disturbance effects may be particularly apparent in more sheltered, stable habitats, than in more disturbed mobile sediments (Kaiser & Spencer, 1996). Resistance is, therefore, assessed as **None** and resilience as **Medium** with a sensitivity of **Medium** to the extraction of substratum to 30 cm.

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

SS.SMu.CFiMu.BlyrAchi can be affected by fishing activity in areas such as the northern Irish Sea, where the community may also contain *Nephrops norvegicus* (Mackie *et al.*, 1995). Populations of *Brissopsis lyrifera* are likely to be reduced owing to damage inflicted to the 'test' by the fishing gear, and broken tests may be seen on the seabed (E.I.S. Rees, M. Costello, pers comm. to Connor *et al.*, 2004). Similar evidence has been reported for other heart urchins. For example, Houghton *et al.* (1971), Graham (1955), de Groot & Apeldoorn (1971) and Rauck (1988) refer to significant trawl-induced mortality of heart urchin *Echinocardium cordatum*. A substantial reduction in the numbers of *Brissopsis lyrifera* due to physical damage from scallop dredging has been reported by Eleftheriou & Robertson (1992). Overall, species with brittle, hard tests are regarded to be sensitive to impact with scallop dredges (Kaiser & Spencer, 1995; Bradshaw *et al.*, 2000; Bergman & van Santbrink, 2000).

Brittlestars have fragile arms that are likely to be damaged by abrasion or physical disturbance. However, brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration (Sköld, 1998). *Amphiura chiajei* burrows in the sediment and extends its arms across the sediment surface to feed. Ramsay *et al.* (1998) suggest that *Amphiura* species may be less susceptible to beam trawl damage than other species of echinoid or tube dwelling amphipods and polychaetes. Bergman & Hup (1992) for example, found that beam trawling in the North Sea had no significant direct effect on small brittlestars. Bradshaw *et al.* (2002) noted that the brittlestars *Ophiocomina nigra*, *Ophiura albida* and *Amphiura filiformis* had increased in abundance in a long-term study of the effects of scallop dredging in the Irish Sea.

The infaunal position occupied by species in this biotope may provide some protection from abrasion at the surface only. However, burrow structures may collapse and flatten other small-scale habitat features, recovery from which may result in some subsequent energy costs associated (Tillin & Hull, 2013a).

Kaiser *et al.* (2006) undertook a meta-analysis of different fishing gears on a range of habitats. The authors concluded that the footprint of the impact and the recovery of communities varied with gear and habitat types. For example, beam trawling and scallop dredging had significant negative short-term impacts in sand and muddy-sand habitats; and mud habitats were shown to have substantial initial impacts by otter trawling but the effects tended to be short-lived with an apparent long-term positive post-trawl disturbance response from the increase of small-bodied fauna.

Furthermore, SS.SMu.CFiMu.BlyrAchi occurs in silty 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 re-suspension 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).

Sensitivity assessment. Although burrowing life habits may provide some protection from damage by abrasion at the surface, the fragile tests and arms of *Brissopsis lyrifera* and *Amphiura chiajei*, respectively, the characterizing species in this biotope, are likely to be adversely affected during abrasion events. Furthermore, the nature of the soft sediment where they occur means that objects causing abrasion, such as fishing gears (including pots and creels) are likely to penetrate the surface and cause further damage to the characterizing species. Resistance is therefore assessed as **Low** and resilience as **Medium**, so sensitivity is assessed as **Medium**.

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

The two key species in the biotope, *Brissopsis lyrifera* and *Amphiura chiajei*, are infauna found close to the sediment surface. The biotope occurs in silty muds (Connor *et al*., 2004) so penetrative activities (e.g. anchoring, scallop or suction dredging) and damage to the seabed's sub-surface is likely to remove and/or damage the infaunal community, including the characterizing species, given the fragility of the tests and that bottom fishing gears penetrate deeper into softer sediments (Bergman & van Santbrink, 2000). Overall, species with brittle, hard tests are regarded to be sensitive to impact with scallop dredges (Kaiser & Spencer, 1995; Bradshaw *et al*., 2000; Bergman & van Santbrink, 2000).

Furthermore, penetrative events caused by a passing fishing gear are also likely to have marked impacts on the substratum and cause turbulent re-suspension 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). 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).

Sensitivity assessment: The biotope could be lost or severely damaged, depending on the scale of the activity (see abrasion pressure). Therefore, a resistance of **None** is suggested. Resilience is probably **Medium**, and therefore the biotope's sensitivity to this pressure is likely to be **Medium**.

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

Clogging of feeding apparatus by suspended sediment is not a consideration for the characterizing species of this biotope. *Brissopsis lyrifera* and *Amphiura chiajei* are burrowing infauna and non-selective surface and sub-surface deposit feeders. For most benthic deposit feeders, food is suggested to be a limiting factor for body and gonad growth, at least between events of sedimentation of fresh organic matter (Hargrave, 1980; Tenore, 1988). Consequently, increased organic matter in suspension that is deposited may become incorporated into sediments via bioturbation and may enhance food supply. A decrease in the suspended sediment and hence siltation may reduce the flux of particulate material to the seabed. Since this includes organic matter the supply of food to the biotope would probably also be reduced. Although characteristically a sub-surface deposit feeder, *Brissopsis lyrifera* has been observed to increase its surface feeding (apical tuft becomes visible) activity after addition of organic matter to the sediment surface and utilized the material for growth (Hollertz *et al*., 1998; Hollertz, 1998). This suggests that an increase in siltation may be beneficial to the population.

Where a change in suspended solids results in increased turbidity and change of light, the community is unlikely to be directly affected. However, increased turbidity may hinder predation by visual predators such as *Nephrops norvegicus*, dab *Limanda limanda*, and haddock *Melanogrammus aeglefinus* upon *Amphiura chiajei*. There may be some increased energetic costs experienced by certain species, associated with increased turbidity, but effects are not likely to be significant. The community is also unlikely to be directly affected by increased light penetration of the water column caused by a decrease in turbidity. Greater light penetration of the water column may improve primary production by phytoplankton in the water column and contribute to secondary productivity via the production of detritus from which the community may benefit.

Sensitivity assessment: An increase in the suspended matter settling out from the water column to the substratum may increase food availability. On the other hand, decreased siltation is unlikely to affect the mainly deposit feeding community that occurs in SS.SMu.CFiMu.BlyrAchi. Resistance and resilience are assessed as **High** and the biotope, therefore, considered to **Not Sensitive** to a change in suspended solids at the pressure benchmark level.

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

Little or no direct evidence for the effects of siltation on the characterizing species of this biotope, *Amphiura chiajei* and *Brissopsis lyrifera*, was found. Last *et al*. (2011) buried *Ophiura ophiura* individuals under three different depths of sediment; shallow (2 cm), medium (5 cm) and deep (7 cm). The results indicated that *Ophiura ophiura* is highly tolerant of short-term (32 days) burial events, with less than 10% mortality of all buried specimens. This is largely a reflection of the ability of the species to re-emerge from all depths across all sediment fractions tested. Survival of specimens that remained buried was low, with 100% mortality of individuals that remained buried after 32 days. The experiments utilized three different fractions of kiln dried, commercially obtained marine sediment: coarse (1.2-2.0 mm diameter), medium fine (0.25-0.95 mm diameter) and fine (0.1-0.25 mm diameter).

Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which *Echinocardium cordatum* could migrate was approximately 30 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. *Brissopsis* is a burrower, adapted to life within sediments and therefore likely to be able to move within sediments although the character of the overburden will determine some degree of the impact. However, there may be some energetic cost expended to either re-establish burrow openings in the case of *Nephrops norvegicus* or to self-clean feeding apparatus as a result of this pressure, though this is not likely to be significant. Both *Brissopsis lyrifera* and *Amphiura chiajei* live buried in muddy sediments up to 2-5 and 6 cm deep, respectively. Being adapted for burrowing means these species are likely to resist additional fine sediment. However, it should be remembered that smothering by impermeable or viscous materials is likely to have some effect on the animals, e.g. by causing de-oxygenation.

Sensitivity assessment. The characterizing species in this biotope are burrowers and therefore likely to be able to move within the sediment deposited as a result of a deposition of 5 cm of sediment. Resistance is assessed as **High** and resilience as **High** (by default) and the biotope is considered **Not Sensitive** to this pressure at the benchmark level.

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

Little or no direct evidence for the effects of siltation on the characterizing species of this biotope, *Amphiura chiajei* and *Brissopsis lyrifera*, was found. Last *et al*. (2011) buried *Ophiura ophiura* individuals under three different depths of sediment; shallow (2 cm), medium (5 cm) and deep (7 cm). The results indicated that *Ophiura ophiura* is highly tolerant of short-term (32 days) burial events, with less than 10% mortality of all buried specimens. This is largely a reflection of the ability of the species to re-emerge from all depths across all sediment fractions tested. Survival of specimens that remained buried was low, with 100% mortality of individuals that remained buried after 32 days. The experiments utilized three different fractions of kiln dried, commercially obtained marine sediment: coarse (1.2-2.0 mm diameter), medium fine (0.25-0.95 mm diameter) and fine (0.1-0.25 mm diameter).

Bijkerk (1988, results cited from Essink, 1999) indicated that the maximal overburden through which *Echinocardium cordatum* could migrate was approximately 30 cm in sand. No further information was available on the rates of survivorship or the time taken to reach the surface. *Brissopsis* is a burrower, adapted to life within sediments and therefore likely to be able to move within sediments although the character of the overburden will determine some degree of the impact. However, there may be some energetic cost expended to either re-establish burrow openings in the case of *Nephrops norvegicus* or to self-clean feeding apparatus as a result of this pressure, though this is not likely to be significant. Both *Brissopsis lyrifera* and *Amphiura chiajei* live buried in muddy sediments up to 2-5 and 6 cm deep, respectively. Being adapted for burrowing means these species are likely to resist additional fine sediment. However, it should be remembered that smothering by impermeable or viscous materials is likely to have some effect on the animals, e.g. by causing de-oxygenation.

Studies by Maurer *et al.* (1986) analysed the ability to vertically migrate and survival responses of three major taxa (polychaetes, crustacean and molluscs) when exposed to a simulated disposition of dredged materials (0-40 cm). Their results suggested that there was evidence of synergistic effects on burrowing activity and mortality with changes in time of burial sediment depth, sediment type and temperature. Significant mortality was observed among all taxa under the maximum overburden by sand or fine sediment with varying contents of silt-clay.

Sensitivity assessment: The characterizing species in this biotope are burrowers and therefore likely to be able to move within the deposited sediment. However, a deposition of 30 cm of fine sediment is likely to result in a significant overburden of the infaunal species and, as a result, there may be some mortality of the characterizing species. Resistance is therefore assessed as **'Medium'** and resilience as '**High**' and the biotope is considered to have a '**Low**' sensitivity to this pressure at the benchmark level.

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 is available on which to assess this pressure.

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

No Evidence was available on which to assess this pressure.

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

SS.SMu.CFiMu.BlyrAchi is a sublittoral biotope (Connor *et al.*, 2004), not characterized by the presence of primary producers and is, therefore, not directly dependent on sunlight. **Not Relevant.**

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. Barriers and changes in tidal excursion are not relevant to biotopes restricted to open waters.

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.

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

Although some species within the community have visual perception e.g. *Nephrops norvegicus*, detecting the presence of boats or machinery, is likely to be beyond their visual acuity. Additionally, some response to visual disturbance has been detected in echinoderms. However, *Brissopsis lyrifera* lives buried in muddy substrata up to 10 cm deep thus visual disturbance was not considered relevant to this species.

Brittlestars exhibit a wide range of responses to light intensity, from a largely indifferent behaviour to pronounced colour changes and rapid escape behaviour. Aizenberg *et al.* (2001) reported that certain calcite crystals used by brittlestars for skeletal construction are also a component of a specialised photosensory organ. However, these structures are absent in light indifferent species. Thus, *Amphiura chiajei* may have visual perception but is likely to have poor visual acuity.

Sensitivity assessment: No adverse effects are expected for the characterizing species of this biotope as a result of this pressure. Resistance and resilience are, therefore, assessed as **High** and the biotope considered **Not Sensitive** to visual disturbance at the pressure benchmark level.

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 key characterizing species in the biotope are not cultivated in the British Isles or likely to be translocated. This pressure is therefore considered **Not Relevant**.

Introduction or spread of invasive non-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

There are no records of the introduction or spread of non-indigenous species in this biotope. This pressure is therefore considered **Not Relevant**.

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

The occurrence of the ascothoracidan parasite *Ulophysema öresundense* (Brattström) has been observed in the body cavity of *Brissopsis lyrifera* (Brattström, 1946). This parasite may cause sexual castration but no further information concerning the effect of this parasite on the population was found. No pathogens are known to affect *Amphiura chiajei*.

The only major biological agent known to affect a species in this biotope is the dinoflagellate parasite, *Hematodinium* spp., now prevalent in *Nephrops norvegicus* populations from the west of Scotland, Irish Sea and North Sea (Field *et al*., 1992). The *Hematodinium* parasite occurs in the blood and connective tissue spaces and appears to cause death in the host by blocking the delivery of oxygen to the host's tissues (Taylor *et al*., 1996). Heavily-infested animals become moribund, spend more time out of their burrows and are probably less able to evade capture by predators or fishing gear. However, the ecological consequences of this infestation are unknown and evidence suggests that the *Nephrops* stocks have not been seriously affected (Hughes, 1999b).

Sensitivity assessment. No evidence of losses of this biotope due to disease were found and it is likely that microbial pathogens will have only a minor possible impact on this biotope. Resistance and resilience are therefore assessed as **High** and the biotope judged as **Not Sensitive** to the introduction of microbial pathogens.

Removal of target species	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. Although *Brissopsis lyrifera* and *Amphiura chiajei* are not targeted by fisheries, dredging operations may adversely affect these species by removal or damage.

Nephrops norvegicus is now one of the most valuable shellfish resources in the north-eastern Atlantic (Hughes, 1998b), and is harvested by static and mobile gears. No evidence was found for the proportion of the population that is removed by targeted harvesting. Video studies have found that only a low proportion (circa 5%) of *Nephrops* that approached creels entered them (Bjordal, 1986; Adey, 2007, cited in Ungfors *et al*., 2013). Factors that govern emergence will influence catch rates as only individuals that have emerged from burrows will be caught by trawl hauls. The degree of emergence from burrows for feeding or mating appears to be mainly governed by light intensities and therefore depends on factors such as time of day and season and varies between populations at different depths (Katoh *et al*., 2013). Experimental trawling (Ameyaw-Akumfi & Naylor, 1987) to evaluate catch rates showed that catchability varied between vessels in the same area and that catch rates were strongly linked to tidal cycles with increased catch rates at spring rather than neap tides. Catch rates differed between genders (Ungfors *et al*., 2013 and references therein), berried females tend to stay within burrows and are rarely caught in trawls (Aguzzi & Sarda, 2008, cited in Katoh *et al*., 2013).

Furthermore, commercial fisheries may result in discarding of damaged or undersized target species. This will increase the available food supply but may also attract mobile predators and scavengers including fish and crustaceans, which may alter predation rates in the biotope.

Sensitivity assessment: The biotope supports *Nephrops norvegicus*, a species targeted by fisheries, lending the characterizing species of this biotope vulnerable to damage or removal by fishing gears. However, only the biological and ecological effects on the biotope are assessed under this pressure. Records indicate that *Nephrops norvegicus* does not occur in all examples of the biotope (Connor *et al*., 2004) suggesting that that biotope's main character and component species are unlikely to be adversely affected by the targeted removal of *Nephrops norvegicus*. Resistance is therefore assessed as **High** and resilience as **High** (by default), so the biotope is considered **Not Sensitive** to removal of targeted species.

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

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 this biotope, including the characterizing species *Brissopsis lyrifera* and *Amphiura chiajei*, may be damaged or directly removed by static or mobile gears that are targeting other species, with reports of high levels of mortality of both characterizing species (see abrasion and penetration of the seabed pressures). Where heavy demersal fishing occurs populations of *Brissopsis lyrifera* may be reduced owing to damage inflicted to the 'test' by the fishing gear. Broken tests may be seen on the sea bed (E.I.S. Rees, M. Costello pers. comm. in Connor *et al*., 2004). Munday (1993) observed that 99% of *Amphiura chiajei* showed evidence of arm tip regeneration in the population off Killary Harbour. Whilst benthic trawling may contribute to arm damage, sub-lethal levels of predation appeared to be the main causative factor for regeneration and was a persistent experience.

Furthermore, commercial fisheries may discard damaged or dead non-target species, which could result in increased available food supply to detritus feeding such as the characterizing species of this biotope that may have survived in the area targeted by fisheries, but may also attract mobile predators and scavengers including fish and crustaceans which may alter predation rates in the biotope.

Sensitivity assessment. The evidence suggests that some loss of the characterizing species is likely to occur as a result of unintentional removal. Removal of *Brissopsis lyrifera* and *Amphiura chiajei*, the characterizing species of this biotope, would result in the biotope being lost. Thus, the biotope is considered to have **Low** resistance to this pressure and to have **Medium** resilience, resulting in the sensitivity being judged as **Medium**.

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