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Dense brittlestars with sparse *Ascidia mentula* and *Ciona intestinali*s on sheltered circalittoral mixed substrata

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

Eliane De-Bastos & Jacqueline Hill

2016-01-25

This review can be cited as:
De-Bastos, E.S.R. & Hill, J., 2016. Dense brittlestars with sparse [Ascidia mentula] and [Ciona intestinali]s on sheltered circalittoral mixed substrata. 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.1067.1

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Dense brittlestars with sparse *Ascidia mentula* and *Ciona intestinalis* on sheltered circalittoral mixed substrata
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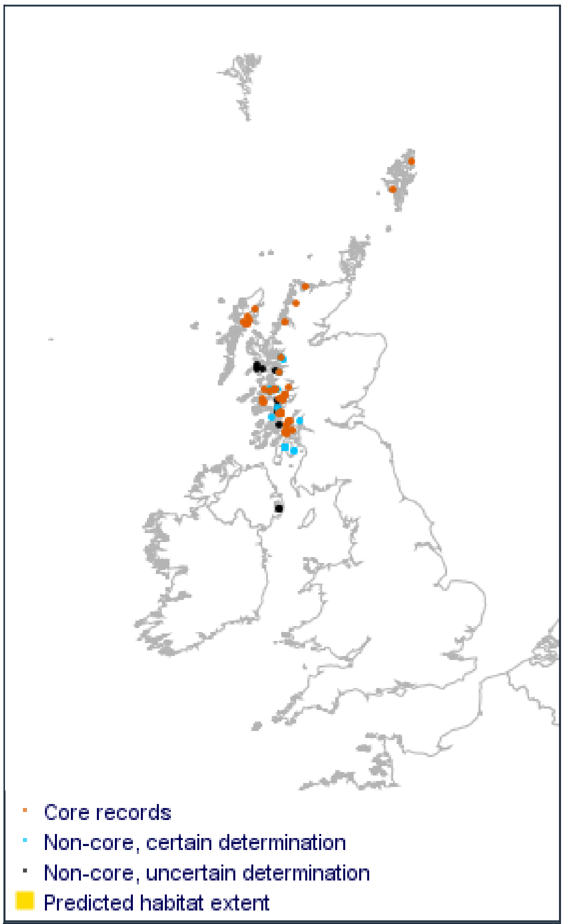

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Eliane De-Bastos & Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A4.3112	Dense brittlestars with sparse *Ascidia mentula* and *Ciona intestinalis* on sheltered circalittoral mixed substrata
JNCC 2015	CR.LCR.BrAs.AmenCio.Bri	Dense brittlestars with sparse *Ascidia mentula* and *Ciona intestinalis* on sheltered circalittoral mixed substrata
JNCC 2004	CR.LCR.BrAs.AmenCio.Bri	Dense brittlestars with sparse *Ascidia mentula* and *Ciona intestinalis* on sheltered circalittoral mixed substrata
1997 Biotope		

Description

This biotope is typically found on wave-sheltered sites (although it may be found in wave-exposed through to extremely wave-sheltered conditions), on circalittoral mixed substrata (bedrock, boulders, cobbles, pebbles and gravel), subject to moderately strong to weak tidal streams. This biotope often has a silty appearance in parallel with AmenCio.Ant but is characterized by a dense carpet of brittlestars (*Ophiothrix fragilis*, *Ophiocomina nigra* and to a lesser extent *Ophiura albida*) which virtually cover the seabed. Where the underlying substratum is visible, pink coralline crusts and the white calcareous tubes of the keelworm *Spirobranchus triqueter* (syn. *Pomatoceros triqueter*) are often observed. Hydroids and bryozoans are scarce, perhaps partly due to the smothering effect of the brittlestars and possibly due to the grazing pressure of the sea urchin *Echinus esculentus* which is occasionally recorded. Other echinoderms present include *Asterias rubens* and *Crossaster papposus*. The solitary ascidian *Ciona intestinalis* may be seen attached to isolated rocks and boulders, whilst on the tops and sides of larger boulders, dead man's fingers *Alcyonium digitatum* may be recorded. The hermit crab *Pagurus bernhardus* is often recorded, whilst under boulders and in crevices the claws belonging to the long-clawed squat lobster *Munida rugosa* may be seen. (Information from Connor *et al.*, 2004; JNCC, 2105).

Depth range

5-10 m, 10-20 m, 20-30 m, 30-50 m

Additional information

-

Listed By

- none -

Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotopes CR.MCR.EcCr.CarSp.Bri, CR.MCR.EcCr.FaAlCr.Bri and CR.LCR.BrAs.AmenCio.Bri are characterized by dense brittlestar beds overlying a sparse grazed faunal turf (Connor et *al*., 2004). The brittlestars form such dense beds that the seabed underneath may not be visible. *Ophiothrix fragilis* is usually the most dominant species in shallow water, with *Ophiocomina nigra* usually found amongst them, but sometimes becoming the dominant species in deeper water. *Ophiura albida* may also be present in CR.MCR.EcCr.FaAlCr.Bri and CR.LCR.BrAs.AmenCio.Bri. CR.MCR.EcCr.CarSp.Bri is typically found on the upper faces of wave-exposed circalittoral bedrock or boulders subject to moderately strong to weak tidal streams, on open coasts. CR.MCR.EcCr.FaAlCr.Bri is typically found on the upper faces of exposed and moderately wave-exposed circalittoral bedrock, boulders and cobbles subject to moderately strong to weak tidal streams, but with only robust hydroids and no sponges. CR.LCR.BrAs.AmenCio.Bri is found on wave sheltered sites (although it may be found in wave exposed through to extremely wave sheltered conditions), on circalittoral mixed substrata (e.g. bedrock, boulders, cobbles, pebbles and gravel), subject to moderately strong to weak tidal streams and is heavily silted compared to the other two biotopes and grazed so that only sparse fauna occur under the brittlestar bed (see Connor *et al*., 2004).

Although brittlestar biotopes are typically species poor, the underlying fauna of the variant CR.MCR.EcCr.CarSp.Bri is relatively diverse. Species such as the anemone *Urticina felina*, the cup coral *Caryophyllia smithii*, and the anemone *Corynactis viridis* may occasionally be present. There may also be sparse clumps of various hydroids including *Halecium halecinum*, *Nemertesia antennina*, *Nemertesia ramosa*, *Sertularella gayi* and *Abietinaria abietina*. The soft coral *Alcyonium digitatum* is occasionally present and there may be sparse specimens of the sponges *Cliona celata* and *Polymastia boletiformis*. In addition, various echinoderms such as *Asterias rubens*, *Antedon bifida*, *Echinus esculentus*, *Henricia oculata*, *Marthasterias glacialis* and *Luidia ciliaris* may be observed. The barnacle *Balanus crenatus* and the polychaete *Spirobranchus triqueter* (syn. *Pomatoceros triqueter*) may be seen attached to any available space on the bedrock and boulders not covered by brittlestars. Bryozoan crusts such as *Parasmittina trispinosa* may also be present. The rocky substratum of the variant CR.MCR.EcCr.FaAlCr.Bri is usually colonized by species such as encrusting red algae and the white, calcareous tubes of the polychaete *Spirobranchus triqueter*. Only robust hydroids such as *Abietinaria abietina*, *Alcyonium digitatum* and bryozoan crusts such as *Parasmittina trispinosa* are able to tolerate the significant smothering effect from the dense mat of brittlestars. Other species typically include *Echinus esculentus*, *Asterias rubens*, *Pagurus bernhardus*, *Anapagurus hyndmanni*, *Gibbula cineraria*, *Urticina felina*, *Pododesmus patelliformis* and *Ciona intestinalis*. Where the underlying fauna of the variant CR.LCR.BrAs.AmenCio.Bri is visible, pink coralline crusts and the white calcareous tubes of the keelworm *Spirobranchus triqueter* are often visible. Hydroids and bryozoans are scarce, perhaps partly due to the smothering effect of the brittlestars and possibly due to the grazing pressure of the sea urchin *Echinus esculentus* which is occasionally recorded. Other echinoderms present include *Asterias rubens* and *Crossaster papposus*. The solitary ascidian *Ciona intestinalis* may be seen attached to isolated rocks and boulders, whilst on the tops and sides of larger boulders, *Alcyonium digitatum* may be recorded. The hermit crab *Pagurus bernhardus* is often recorded, whilst under boulders and in crevices the claws belonging to the long-clawed squat lobster *Munida rugosa* may be seen.

As the underlying fauna in these variants resemble that of CarSp.PenPcom, FaAlCr and AmenCio (respectively) removal of the characterizing mat of brittlestars would likely lead to re-classification and loss of the biotopes. The sensitivity assessments therefore focus on the brittlestar beds. Whenever possible, the sensitivity of the other important characteristic species is described, including coralline crusts, *Parasmittina trispinosa*, *Caryophyllia smithii*, *Ascidia mentula* and *Ciona intestinalis.*

Resilience and recovery rates of habitat

The biotopes are characterized by dense mats of brittlestars. There is disagreement concerning the lifespan of the main bed forming brittlestar *Ophiothrix fragilis*. Davoult *et al.* (1990) suggested a lifespan of 9 -20 months. Taylor (1958, quoted in Gorzula, 1977) recorded that *Ophiothrix* reached a disc diameter of about 14 mm in two years, and that most individuals died after spawning in their second summer. However, other researchers have considered the animals to be much longer-lived. Gorzula (1977) quotes evidence that Swedish *Ophiothrix* can live for up to eight years. A lifespan of over nine years has been suggested based on counts of growth bands in the skeletal arm plates of *Ophiothrix* (Gage, 1990). It is possible that growth rates may vary widely in different areas, or that the different varieties of *Ophiothrix fragilis* recognised by French workers may have contrasting population dynamics.

Ophiothrix fragilis has an extended breeding season running roughly from April to October (Smith, 1940; Ball *et al*., 1995). In the Dover Strait, the main period of larval settlement was in September/October, but settlement also occurred in February, April and June (Davoult *et al*., 1990). Maximum population densities (approximately 2000 individuals /m^2) were found during the main recruitment period in September (Davoult *et al*., 1990). A similar seasonal pattern was found by Brun (1969) in the Isle of Man, where newly-settled juveniles were found in August and September. Peak juvenile numbers occurred in November in a Bristol Channel population (George & Warwick, 1985). In Kinsale Harbour, Ireland, post-settlement juveniles could be found throughout the year, with maximum numbers (up to 1000 juveniles /m^2) in October (Ball *et al*., 1995). Mortality was high, leading to low levels of recruitment into the adult population. All studies agree that recruits initially settle on the arms of adults. Lost populations may not always be replaced because settlement of larvae of *Ophiothrix fragilis* is highly dependent on hydrographic conditions and consequently may be unpredictable. In the strong water currents of the English Channel, larvae can disperse up to 70-100 km and establish populations elsewhere (Pingree & Maddock, 1977). Therefore, if hydrographic conditions change recruitment may fail and lost populations may not be replaced. For example, dense aggregations of *Ophiothrix fragilis* in the Plymouth area have not recovered since their decline in the 1970's. It was suggested that changes in the oceanographic cycle affecting the western Channel resulted in increased predation pressure from *Luidia ciliaris* and also recruitment failure of *Ophiothrix fragilis* (Holme, 1984). If any adults remain, aggregations may re-establish as individual brittlestars tend to crawl back and forth across water currents until a conspecific is found (Broom, 1975).

Ophiocomina nigra grows slowly and lives for up to 14 years (Hughes, 1998b). Juvenile *Ophiocomina* appear not to settle among adults. The Firth of Clyde populations studied by Gorzula (1977) were each dominated by a single size-class of animals, suggesting that each *Ophiocomina* bed is formed by a single settlement of juveniles, which thereafter receives little or no recruitment.

Coralline crusts, *Parasmittina trispinosa and Caryophyllia smithii* are characterizing species of the CR.MCR.EcCr.CarSp.Bri biotope. Studies by Edyvean & Forde (1984a; 1986; 1987) of populations of coralline crusts, namely *Lithophyllum incrustans*, suggest that reproduction may be sexual or asexual (on average early in the third year), and spores are released throughout the year with seasonal variation as less spores were produced in the summer. The authors also found that spore survival was extremely low and young mortality was high, but individuals after the age of 10 appear relatively long-lived (up to 30 years). Some repair of damaged encrusting coralline occurs through vegetative growth, so recolonization by propagules may also be an important mechanism for rapid recovery (Chamberlain, 1996; Airoldi, 2000). There is sparse information regarding the life history traits of *Parasmittina trispinosa*. Eggleston (1972a) noted in the Isle of Man, a peak in reproductive and vegetative growth was not well marked, and the number of embryos present is fairly constant throughout the year, indicating that *Parasmittina trispinosa* could potentially reproduce annually within the UK. *Caryophyllia smithii* is a small (max 3 cm across) solitary coral common within tide swept sites of the UK (Wood, 2005). It was suggested by Fowler & Laffoley (1993) that *Caryophyllia smithii* was a slow growing species, which suggests that inter-specific spatial competition with colonial faunal or algae species are important factors in determining local abundance (Bell & Turner, 2000). *Caryophyllia smithii* reproduces sexually with gamete release most likely triggered by seasonal temperature increases (typically from January-April) (Tranter *et al*., 1982). The pelagic stage of the larvae may last up to 10 weeks, which provides this species with a good dispersal capability (Tranter *et al*., 1982).

Sparse *Ascidia mentula* and *Ciona intestinalis* characterize the biotope CR.LCR.BrAs.AmenCio.Bri. Both are large solitary sea squirts growing up to 18 and 15 cm in length, and living up to 7 and 2 years, respectively. Breeding in both species occurs throughout the year (but predominantly during the summer for *Ascidia mentula*), with fertilization occurring externally and a short planktonic phase (Rowley, 2008). In *Ciona intestinalis*, spawning seems to be triggered by changes in light, and embryonic development seems to be temperature dependent. Larvae of this species may either disperse in the plankton or be retained until settlement, which may explain the dense aggregations of adults of these species (Jackson, 2008).

Other species also found in these biotopes include *Corynactis viridis, Urticina felina, Echinus esculentus* and *Alcyonium digitatum.* Hiscock *et al.* (2010) recorded the succession of the biological community on the wreck for 5 years following the sinking of the ship *Scylla*, which was intentionally sunk on March 2004 in Whitsand Bay, Cornwall to act as an artificial reef. Initially the wreck was colonized by opportunistic species; filamentous algae, hydroids, serpulid worms and barnacles. *Corynactis viridis* was first recorded in the summer of the first year and quickly formed colonies via asexual reproduction. *Alcyonium digitatum* was first recorded within the first year after the vessel was sunk but colonies did not become a visually dominant component of the community until 2009; 5 years after the vessel had been sunk. *Echinus esculentus* and *Urticina felina* colonized ex-HMS *Scylla* in the third and fourth year. *Echinus esculentus* was among those expected but were either not seen or in low abundance by 2009.

Hydroids are considered to have high rates of recovery (resilience), given that they exhibit rapid rates of recovery from disturbance through repair, asexual reproduction and larval colonization (Gili & Hughes, 1995). Other species found within these biotopes such as *Spirobranchus triqueter* also recover annually (Tillin & Tyler-Walters, 2014, references therein) and are often the first organisms to colonize available space in settlement experiments.

Resilience assessment: Removal of the brittlestar *Ophiothrix fragilis* and *Ophiocomina nigra* species would likely result in these biotopes being lost and re-classified depending on the underlying fauna. Minor damage to individual brittlestars is likely to be repaired, missing arms that are shed as part of an escape/disturbance response can be regrown (Tillin & Tyler-Walters, 2014). Recovery from impacts with a small spatial footprint may occur through migration of adults and some species such as *Ophiura spp*. are mobile, as shown by bait trapping experiments (Groenewold & Fonds, 2000). Where the majority of the population remain (resistance is High), and/or recruitment by adult mobility is possible resilience is likely to be **'High'**. Where impacts remove a significant proportion of the population, recovery will require larval recolonization, as well as adult migration. Sexual maturity is reached within 2 years and reproduction is annual and protracted providing a supply of larvae. However, brittlestars demonstrate sporadic and unpredictable recruitment (Buchanan, 1964), even though they have long-lived pelagic larvae with a high dispersal potential. Therefore, where a significant part of the population is lost (resistance is **Low** or **None**), recovery is likely to be **'Medium'** (2-10 years). The evidence suggests that Ophiothrix fragilis' recruits initially settle on the arms of adults, but it is not clear whether the presence of adults is a requirement for successful larval re-colonization. The reproductive frequencies, longevity and recruitment observations described above suggest that the remaining characterizing specieis in these biotopes, including the coralline crusts, *Parasmittina trispinosa*, *Caryophyllia smithii*, *Ascidia mentula* and *Ciona intestinalis*, are likely to recruit within the first two years after disturbance and have high resilience.

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

Ophiothrix fragilis is widely distributed in the eastern Atlantic from Norway to South Africa and both *Ophiocomina nigra* and *Ophiura albida* from Norway to the Azores and Mediterranean (Hayward & Ryland, 1995b). Other component species in the biotopes also have a widespread distribution in the north east Atlantic. Consequently, these species are exposed to temperatures both above and below those found in the British Isles and their distribution is not limited by temperature. In the Dutch Oosterschelde Estuary fluctuations in the abundance of *Ophiothrix fragilis* between 1979 and 1990 appeared to be driven by winter temperatures (Leewis *et al.*, 1994). When winter temperatures increased in 1979-80 and 1987-88, populations of brittlestars increased enormously, and occupied 60-90% of the available hard substratum in layers up to 5 cm deep. Populations were reduced to less than 10% following the cold winters in 1978-79, 1984-85 and 1985-86. Thus, increases in temperature may be beneficial to populations. However, short-term acute changes in temperature are noted to cause a reduction in the loading of subcutaneous symbiotic bacteria in echinoderms such as *Ophiothrix fragilis*. Reductions in these bacteria are probably indicative of levels of stress and may lead to mortality (Newton & McKenzie, 1995).

Coralline crusts and *Caryophyllia smithii* characterize the biotope CR.MCR.EcCr.CarSp.Bri. Coralline crusts are found further south than the UK and are considered to tolerate increased temperatures. Edyvean & Ford (1984b) suggested that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity ‘shocks’ induce spawning but no information on thresholds was provided (Edyvean & Ford, 1984b). Wilson (1975) suggested that *Caryophillia smithii* appears to tolerate a wide range of variation in parameters, including temperature. However, although mature examples of *Caryophyllia smithii* were recorded in Greece by Koukouras (2010), unseasonal increases in temperature may disrupt the natural reproductive processes and negatively influence recruitment patterns given that gamete release is most likely triggered by seasonal temperature increases (Tranter *et al*., 1982).

Ciona intestinalis and *Ascidia mentula*, that occur in CR.LCR.BrAs.AmenCio.Bri, are both widely distributed, and appear to tolerate a broad range of temperatures. Tolerance to increases in temperature may vary among geographical populations or ecotypes. Adult *Ciona intestionalis* is reported as tolerant of temperatures up to 30°C (Dybern, 1965; Therriault & Herborg, 2008), although Petersen & Riisgard (1992) noted that filtration rates declined above 21°C which suggested thermal stress. The effect of higher temperatures on *Ascidia mentula* is not as well researched but studies by Glantz (2005) found that increases in temperature could be associated with an increase in population density across all sites in the study.

Sensitivity assessment. The distribution of *Ophiothrix fragilis* and *Ophiocomina nigra*, suggests that they are likely to be tolerant of an acute or chronic temperature increase at the pressure benchmark. Resistance is assessed as ‘**High**’ and resilience as ‘**High’** (by default), so the biotopes are therefore considered to be ‘**Not sensitive’** at the pressure benchmark.

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

Ophiothrix fragilis is widely distributed in the eastern Atlantic from Norway to South Africa and both *Ophiocomina nigra* and *Ophiura albida* from Norway to the Azores and Mediterranean (Hayward & Ryland, 1995b). Other component species in the biotopes also have a widespread distribution in the north east Atlantic. Consequently, these species are exposed to temperatures both above and below those found in the British Isles with distribution not limited by temperature. In the Dutch Oosterschelde Estuary fluctuations in the abundance of *Ophiothrix fragilis* between 1979 and 1990 appeared to be driven by winter temperatures (Leewis *et al*., 1994). When winter temperatures increased in 1979-80 and 1987-88, populations of brittlestars increased enormously, and occupied 60-90% of the available hard substratum in layers up to 5 cm deep. Populations were reduced to less than 10% following the cold winters in 1978-79, 1984-85 and 1985-86. Thus, decreases in temperature may affect population densities. Short-term acute changes in temperature are noted to cause a reduction in the loading of subcutaneous symbiotic bacteria in echinoderms such as *Ophiothrix fragilis*. Reductions in these bacteria are probably indicative of levels of stress and may lead to mortality (Newton & McKenzie, 1995).

Coralline crusts and *Caryophyllia smithii* characterize the biotope CR.MCR.EcCr.CarSp.Bri. Coralline crusts have a wide northern distribution in the UK, so communities in the middle of its range are likely to tolerate a decrease in temperature. Wilson (1975) suggested that *Caryophillia smithii* appears to tolerate a wide range of variation in parameters, including temperature. However, unseasonal decreases in temperature may disrupt the natural reproductive processes and negatively influence recruitment patterns given that gamete release is most likely triggered by temperature (Tranter *et al*., 1982). *Ciona intestinalis* and *Ascidia mentula*, that occur in CR.LCR.BrAs.AmenCio.Bri, are both widely distributed, and appear to tolerate a broad range of temperatures. However, tolerance to decreases in temperature may vary among geographical populations or ecotypes. Svane (1984) found that lower temperatures decreased recruitment of *Ascidia mentula* in Sweden.

Sensitivity assessment. The distribution of *Ophiothrix fragilis* and *Ophiocomina nigra*, the characterizing species of these biotopes are considered likely to be tolerant of an acute or chronic decrease in temperature at the pressure benchmark. Thus, resistance is assessed as '**High**' and resilience as '**High'** (by default) and the biotopes are therefore considered to be '**Not Sensitive'** at the pressure benchmark.

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

Echinoderms are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987; Russell, 2013) and unable to tolerate wide fluctuations in salinity. A review by Russell (2013) confirmed that *Ophiothrix fragilis* and *Ophiocomina nigra* have not been previously recorded in hypersaline conditions, although Pagett (1981) suggested that echinoderms may exhibit localised physiological adaption to reduced or variable salinities in near shore areas subject to freshwater runoffs. However, a circalittoral habitat is less likely to experience variable salinities, and resident species, therefore, less likely to be adapted to variation in salinity, as suggested by the results given by Pagett (1981).

Although crustose corallines are found in rockpools, where salinities may fluctuate markedly during exposure to the air, Edyvean & Ford (1984b) suggested that populations of *Lithophyllum incrustans* are affected by temperature changes and salinity and that temperature and salinity 'shocks' induced spawning but no information on thresholds was provided. Additionally the authors observed that populations of *Lithophyllum incrustans* were less stable in rockpools with a smaller volume of water that were more exposed to temperature and salinity changes due to lower buffering capacity. Wilson (1975) noted that *Caryophillia smithii* appears to tolerate a wide range of variation in parameters, including salinity. Both these species characterize the biotope CR.MCR.EcCr.CarSp.Bri.

Ciona intestinalis has been classified as euryhaline with a high salinity tolerance range (12-40‰) although it typically occurs in full salinity conditions (>30‰) (Tillin & Tyler-Walters, 2014). *Ciona intestinalis* has been found in salinities ranging from 11 to 33 PSU in Sweden, although the same study found that parent acclimation to salinity (high or low) has an overriding and significant effect on larval metamorphic success, independent of parent origins (Renborg *et al.*, 2014). No information on *Ascidia* spp. was found. Both these species characterize the biotope CR.LCR.BrAs.AmenCio.Bri.

Sensitivity assessment. There is little direct evidence of the effects of hypersaline conditions on *Ophiothrix fragilis* and *Ophiocomina nigra*. 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: Medium	Medium Q: High A: Medium C: Medium

Echinoderms are stenohaline owing to the lack of an excretory organ and a poor ability to osmoand ion-regulate (Stickle & Diehl, 1987; Russell, 2013). This means that they are unable to tolerate wide fluctuations in salinity. Although brittlestar beds are generally found in fully marine conditions, Wolff (1968) observed dense aggregations of *Ophiothrix fragilis* occurring in salinities of 16 psu and even persisting down to 10 psu in the Oosterschelde Estuary. Russell (2013) reported that *Ophiocomina nigra* and *Ophiura albida* can tolerate 27.6‰ and 20‰ in experiments, respectively. Pagett (1981) suggested that localised physiological adaption to reduced or variable salinities may occur in near shore areas subject to freshwater runoffs However, a circalittoral habitat 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).

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Ciona intestinalis and *Ascidia mentula* are typically found in full salinity conditions, but both have been found in lower salinities. *Ciona intestinalis* has been reported in Scandinavian waters in salinities as low as 11 ‰ (Renborg *et al.*, 2014; Dybern, 1967). *Ascidia mentula* has been found in a brackish lake in Corsica with a salinity gradient of 6.5 to 18.5 ‰ Cl^- (Verhoeven & Van Vierssen, 1978). However, studies by Lambert & Lambert (1998) and Caputi *et al.* (2015) have suggested that mortality of *Ciona intestinalis* in California and in the Mediterranean, respectively, could be associated with low salinities, and adult acclimation to salinity was shown to have an overriding and significant effect on larval metamorphic success, independent of parent origins (Renborg *et al.*, 2014). Both these species characterize the biotope CR.LCR.BrAs.AmenCio.Bri.

Sensitivity assessment. The evidence suggests that a decrease in salinity may result in significant mortality of the biotopes' defining species, *Ophiothrix fragilis*, especially as populations in the circalittoral may not be adapted to tolerate variations in salinity. Resistance is therefore assessed as '**Low**' and resilience as '**Medium**'. Sensitivity is therefore assessed as '**Medium'**.

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

Dense brittlestar beds are found in a range of water flows from sea lochs with restricted water flows to higher-energy environments on open coastlines (Connor *et al.*, 2004). In the Dover Strait, *Ophiothrix* beds experience current speeds of up to 1.5 m/s during average spring tides (Davoult & Gounin, 1995). Davoult & Gounin (1995) found that current speeds below 0.2 m/s were optimal for suspension feeding by *Ophiothrix fragilis*. If the velocity exceeded 0.3 m/s the animals ceased feeding, flattening themselves against the substratum and linking arms, so increasing their collective stability in the current. These values agree with those found by Warner (1971).

Similarly strong tidal streams (1.0-1.2 m/s) were also recorded over beds in the Isle of Man (Brun, 1969). In both locations (Isle of Man and the Dover Strait), *Ophiothrix* densities of up to 2000 individuals/m^2 were recorded. Hughes (1998b) suggested that high density aggregations could probably only be maintained where strong currents can supply enough suspended food. Food requirements probably set a lower limit on the current regime of areas able to support brittlestar beds. However, above a certain water speed (0.25 m/s) the feeding arms are withdrawn from the water column (Warner & Woodley, 1975; Hiscock, 1983). At water speeds above about 0.28 m/s individuals or even small groups may be displaced from the substratum and they have been observed being rolled along the seabed by the current (Warner, 1971). Living in dense aggregations may reduce displacement by strong currents (Warner & Woodley, 1975). *Ophiocomina nigra* is usually found in fairly sheltered sites with some water movement, and within these biotopes tends to become more dominant in deeper water than *Ophiothrix* (Connor *et al*., 2004), which suggests a lower resistance to changes in water flow.

Parasmittina trispinosa, the coralline crusts and ascidians are characterizing species of the biotopes CR.MCR.EcCr.CarSp.Bri and CR.LCR.BrAs.AmenCio.Bri, respectively, and are flat and securely attached, so likely to be subjected to little or no drag. However, where a change in tidal current includes a significant and prolonged decrease in water flow, the groups may be affected by a reduction of nutrient supply and possible deposition of sediment (see siltation pressure). In the case of the low energy biotope CR.LCR.BrAs.AmenCio.Bri, an increase in water flow rate may impact on the characterizing species of this biotope *Ciona intestinalis* and *Ascidia mentula* due to lower tolerance to physical damage by scour.

Caryophyllia smithii, that occurs in CR.MCR.EcCr.CarSp.Bri, like other suspension feeders in these biotopes, relies on water currents to supply food. Additionally, it is capable of living in strong to weak currents and, although feeding in particular might be affected, it is not thought that individuals will be killed by increases or decreases in flow rate (Tillin & Hull, 2013g).

Sensitivity assessment. The evidence available suggests that brittlestars have behavioural adaptations to changes in water flow (Tillin & Tyler-Walters, 2014). Increased flow rates, increases suspension and transport of organic particles and can enhance feeding rates. If the flow is too strong, brittlestars may flatten, link arms, or withdraw arms into sediment. At lower flow rates species may switch to deposit feeding. Thus, although brittlestar beds can tolerate increased water flow over tidal cycles a long-term increase will probably prevent the population feeding and over a period of a year this is likely to cause the loss of the population. A decrease in water flow could potentially have an effect on some of the characterizing species of the biotopes and may alter species richness as a result of sediment deposition. These are not considered to alter the character of the biotopes. However, these brittlestar dominated biotopes occur in a range of water flows, so the change in the water flow experienced by mid-range populations of the characterizing species is unlikely to have an impact at the pressure benchmark. The biotopes are considered to have '**High**' resistance and '**High**' resilience, and are therefore assessed as '**Not Sensitive'** at the 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 these 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: Low A: Low C: Low	Not sensitive Q: Low A: Low C: Low

Records indicate that CR.MCR.EcCr.CarSp.Bri, and CR.MCR.EcCr.FaAlCr.Bri occur within a range of wave exposure categories, from moderate to extreme wave exposure (Connor *et al*., 2004). Connor *et al*. (2004) also suggested that the depth at which the biotopes occur means that wave action was not severe on the seabed as to displace the dense mat of brittlestars. CR.LCR.BrAs.AmenCio.Bri occurs in low energy areas, in moderate to very sheltered wave exposure (Connor *et al*., 2004), although it probably occurs at greater depth in areas of moderate wave exposure. Therefore, an increase in wave action, and/or the frequency of storms may be detrimental to the brittlestar beds in this variant. A decrease may increase siltation and limit food supply for the dominant suspension feeding community but only where tidal flow is also reduced.

Sensitivity assessment: An increase or decrease in wave height at the pressure benchmark is unlikely to be significant in wave exposed examples of the biotopes. As brittlestar beds require strong to moderate water movements, water flow is probably a more important source of water movement in sheltered examples of the biotopes. Therefore, brittlestar beds probably have a '**High**' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as '**High**', by default, and the biotopes are considered '**Not Sensitive'** at the benchmark level. The low energy biotope AmenCio.Bri occurs in sheltered sea lochs with little water flow but is recorded in moderately exposed conditions, so that the brittlestar bed itself, is probably still 'Not sensitive' at the benchmark level.

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.

Adult echinoderms such as *Ophiothrix fragilis* are known to be efficient concentrators of heavy metals including those that are biologically active and toxic (Ag, Zn, Cd and Co) (Hutchins *et al*., 1996). There is no information available regarding the effects of this bioaccumulation. Gounin *et al*. (1995) studied the transfer of heavy metals (Fe, Mn, Pb, Cu and Cd) through *Ophiothrix* beds. They concluded that heavy metals ingested or absorbed by the animals transited rapidly through the body and were expelled in the faeces and did not appear to accumulate in their tissues. 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.

Regarding the remaining characterizing species of the biotopes CR.MCR.EcCr.CarSp.Bri and CR.LCR.BrAs.AmenCio.Bri, no information was found concerning the effects of heavy metals on encrusting coralline algae or the sensitivity of *Caryophyllia smithii* or *Parasmittina trispinosa* to heavy metal contamination. It is well recognised that ascidians are capable of accumulating trace elements such as heavy metals, but no information is available regarding the effects of this accumulation (Jackson, 2008).

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.

Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995). Adult *Ophiothrix fragilis* have been documented to be intolerant to hydrocarbons (Newton & McKenzie, 1995). The sub-cuticular bacteria that are symbiotic with *Ophiothrix fragilis* are reduced in number following exposure to hydrocarbons. Exposure to 30,000 ppm oil reduces the bacterial load by 50% and brittlestars begin to die (Newton & McKenzie, 1995). The water-accumulated fraction of diesel oil has been found to be acutely toxic to *Ophiothrix fragilis* and *Ophiocomina nigra*, although no field observations of beds being damaged by hydrocarbon pollution have been found (Hughes, 1998b).

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.

Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995) but there is no more detailed information than this broad statement. In laboratory experiments Smith (1968) found the concentration of BP1002 (the detergent used in the *Torrey Canyon* oil spill clean-up) needed to kill the majority of *Ophiocomina nigra* was 5 ppm. Although there are no known examples of brittlestar beds being damaged by chemical pollutants such as pesticides or anti-parasite chemicals used in aquaculture, it is logical to suppose they would be adversely affected.

Regarding the remaining characterizing species of the biotopes CR.MCR.EcCr.CarSp.Bri and CR.LCR.BrAs.AmenCio.Bri, no information could be found relating to the sensitivity of *Caryophyllia smithii*, *Parasmittina trispinosa*, *Ciona intestinalis* or *Ascidia mentula* to synthetic compound contamination. Chamberlain (1996) observed that although *Lithophyllum incrustans* was quickly affected by oil during the *Sea Empress* spill, recovery occurred within about a year. The oil was found to have destroyed about one third of the thallus thickness but regeneration occurred from thallus filaments below the damaged area.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Adult echinoderms such as *Ophiothrix fragilis* are known to be efficient concentrators of radionuclides (Hutchins *et al*., 1996). However, there was no information available about the effect of this bioaccumulation.

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	Medium Q: Medium A: Medium C: Medium	High Q: High A: High C: High	Low Q: Medium A: Medium C: Medium

Cole *et al.* (1999) suggested possible adverse effects on marine species exposed to dissolved oxygen concentrations below 4 mg/l and probable adverse effects below 2mg/l. However, *Ophiothrix fragilis* is known to have a low respiration rate (Migné & Davoult, 1997b), and experiments by Rosenberg *et al.* (1991, cited in Diaz & Rosenberg, 1995) suggested that the higher tolerance to hypoxia shown by *Amphiura chiajei* compared to *Amphiura filiformis* could also be linked to lower respirations rates, although both these brittlestars species were considered to be resistant to moderate hypoxia (Diaz & Rosenberg, 1995, references therein).

Stachowitsch (1984) observed a mass mortality of benthic organisms in the Gulf of Trieste, northern Adriatic Sea, caused by the onset of severe hypoxia (oxygen depletion) in the near-bottom water. A wide variety of organisms were affected, including burrowing invertebrates, sponges, and the brittlestar *Ophiothrix quinquemaculata*, a dominant component of the local epifaunal community. This event was likely caused by a combination of unfavourable weather and tidal conditions, at the same time as a period of maximal organic input from coastal pollution and dying phytoplankton. Water exchange in the Gulf was poor, and the area tended to accumulate sediment and suspended organic material. Very high productivity in the water column, combined with sewage input throughout the summer tourist season, probably led to the consumption of most of the dissolved oxygen by microbial activity. Mortality occurred when the oxygen-deficient water mass extended to the sea floor (Stachowitsch, 1984).

Sensitivity assessment: The evidence presented suggests that some species of brittlestar are likely to tolerate moderate levels of hypoxia. However, Stachowitsch (1984) observed a mass mortality of brittlestar *Ophiothrix quinquemaculata* within 2-3 days of the onset of a hypoxia event. Resistance of the biotopes are assessed as '**Medium**' and recovery assessed as '**High**' resulting in the sensitive of the biotopes being considered '**Low'** at the pressure benchmark.

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

It is thought that dense *Ophiothrix* beds may play an important role in local nutrient cycles by filtration and concentration of suspended particulate matter and by excretion of nitrogenous waste (Hughes, 1998b). Brittlestar beds are therefore likely to be able to resiste increased nutrient levels in the form of dissolved nutrients or particulate matter. For example, in the Bay of Brest in Brittany, Hily (1991) estimated that *Ophiothrix* beds with over 400 individuals/m^2 could filter the equivalent of 30% of the total water volume of the bay daily. The inflow of nutrient-rich stream water into the bay led to very high primary productivity, but eutrophication did not occur, because of the removal of particulate matter by the benthic community of brittlestars. A dense aggregation of *Ophiothrix* and *Ophiocomina* appeared to be unaffected by the presence of a salmon farm within 100 m (B. Ball pers. comm. in Hughes, 1998b). Since such farms often result in an increase in nutrients to the sea bed, brittlestar beds appear to be able to resiste some increase in nutrient levels (Hughes, 1998b). Raymont (1950) recorded an increase in populations of *Ophiocomina nigra* following the addition of fertilizers to the waters of an enclosed basin of Loch Sween, Argyll.

Atalah & Crowe (2010) added nutrients to rockpools in controlled experiments. The rockpools were occupied by a range of algae including encrusting corallines, and also grazers. Their results showed that the cover of coralline crusts was adversely affected by a reduction of nutrients, but only when grazers were removed from the treatments. Although the experimental treatments do not directly relate to the pressure benchmark, they indicate some general trends in sensitivity. Given that grazers are not significant structuring species of these biotopes, and the densities of brittlestars are unlikely to be affected by this pressure, coralline crusts are also unlikely to be affected by this pressure. *Caryophyllia smithii* and *Parasmittina trispinosa* are suspension feeders of phytoplankton and zooplankton. Nutrient enrichment of coastal waters that enhances the population of phytoplankton may be beneficial to *Caryophyllia smithii* and *Parasmittina trispinosa* in terms of an increased food supply, although Hartnoll (1998) found that effects were uncertain for species such as *Alcyonium digitatum*, *Caryophyllia smithii* and *Spirobranchus triqueter*. The survival of *Caryophyllia smithii* and *Parasmittina trispinosa* may be influenced indirectly. High primary productivity in the water column combined with high summer temperature and the development of thermal stratification (which prevents mixing of the water column) can lead to hypoxia of the bottom waters which faunal species are likely to be sensitive to (see de-oxygenation pressure). Coralline crusts, *Caryophyllia smithii* and *Parasmittina trispinosa* are characterizing species of the biotope CR.MCR.EcCr.CarSp.Bri.

Regarding the characterizing species of the biotope CR.LCR.BrAs.AmenCio.Bri, there is some suggestion that there are possible benefits to ascidians from increased nutrient content of water (Naranjo *et al*., 1996). *Ascidia mentula* has been reported in Iberian bays subject to both nutrient-rich upwelling events and anthropogenic pollution (Aneiros, 2015)

Sensitivity assessment. Due to the resistance of high levels of nutrient input demonstrated by species of brittlestars, brittlestar beds may be able to resiste nutrient enrichment. Resistance is assessed as '**High**' and resilience as '**High**' (by default) and the biotopes are considered as '**Not Sensitive**' at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Organic enrichment	High Q: Medium A: High C: Low	High Q: High A: High C: High	Not sensitive Q: Medium A: High C: Low

Organic enrichment may be beneficial to suspension feeders as a direct source of food and may indirectly enhance food supply where enrichment stimulates local growth of phytoplankton and diatoms. Raymont (1950) recorded an increase in *Ophiocomina nigra* populations following the addition of fertilizers to the waters of an enclosed basin of Loch Sween, Argyll. A dense aggregation of *Ophiothrix* and *Ophiocomina* was recorded in 1974 from a site at the mouth of Killary Harbour, western Ireland, and reported unchanged following subsequent establishment of a salmon farm within 100 m of the main beds (B. Ball, pers. comm. cited in Hughes, 1998b). However, high levels of organic enrichment would be expected to result in excessive sedimentation and hypoxia having deleterious effects on brittlestars and other suspension feeders. Stachowitsch (1984) reported that organic pollution may well have contributed to the environmental oxygen depletion causing mass mortality of brittlestar *Ophiothrix quinquemaculata* in the Gulf of Trieste.

The AZTI Marine Biotic Index (AMBI) is a biotic index to assess disturbance (including organic enrichment). Borja *et al.* (2000) assigned *Ophiothrix fragilis* to Ecological Group I (Species very sensitive to organic enrichment and present under unpolluted conditions (initial state) whereas Gittenberger & Van Loon (2011) assigned this 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). *Ophiocomina nigra* has not been assigned an AMBI category. Although the unpublished Gittenberger & Van Loon (2011) report is an update on Borja *et al.* (2000), the former is a peer reviewed publication. Given that the evidence used in both cases is unclear, the degree of confidence is assessed as medium.

Caryophyllia smithii and *Parasmittina trispinosa*, that occur in biotope CR.MCR.EcCr.CarSp.Bri, are suspension feeders of phytoplankton and zooplankton. Organic enrichment of coastal waters that enhances the population of phytoplankton may be beneficial to *Caryophyllia smithii* and *Parasmittina trispinosa* in terms of an increased food supply, so the survival of *Caryophyllia smithii* and *Parasmittina trispinosa* may be influenced indirectly. High primary productivity in the water column combined with high summer temperature and the development of thermal stratification (which prevents mixing of the water column) can lead to hypoxia of the bottom waters which faunal species are likely to be sensitive to (see de-oxygenation pressure).

Regarding the characterizing species of the biotope CR.LCR.BrAs.AmenCio.Bri, there is some suggestion that there are possible benefits to ascidians from increased organic content of water (Naranjo *et al.*, 1996). *Ciona intestinalis* and *Ascidia mentula* have been reported in locations enriched by organic pollutants (Carver *et al.*, 2006; Aneiros, 2015).

Sensitivity assessment: The evidence presented based on the AMBI scores conflicts and considered with caution. These biotopes are generally found in areas with some water movement and this is likely to disperse organic matter reducing organic material load. Resistance to organic enrichment is assessed as '**High**' and resilience as '**High**'. These biotopes are therefore assessed as '**Not Sensitive**' to organic enrichment, and the animals found within the biotopes may be able to utilize the input of organic matter as food, or are likely to be resistant of inputs at the 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 rock were replaced with sediment, this would represent a fundamental change to the physical character of the biotopes and the species would be unlikely to recover. The biotopes would 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)	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' for biotopes that occur on bedrock.

Habitat structure changes - removal of substratum (extraction)	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

Brittlestar beds occur on rocky substrata. The AmenCio.Bri biotope includes mixed substrata (including gavel) but on rock, as no infauna are recorded (Connor *et al.*, 2004). Therefore this pressure is **'Not Relevant'.**

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

Brittlestars are epifaunal and have fragile arms so are likely to be directly exposed and damaged by abrasion. 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). Fishermen tend to avoid brittlestar beds since the animals clog their nets (Jones *et al.*, 2000). However, a passing scallop dredge is likely to remove, displace, or damage brittlestars caught in its path. Although several species of brittlestar were reported to increase in abundance in trawled areas (including *Ophiocomina nigra*), Bradshaw *et al.* (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long-term in areas subject to scallop dredging. Overall, a proportion of the population is likely to be damaged or removed. An average of 36% of individuals in five British brittlestar beds were regenerating arms (Aronson, 1989) which suggests that the beds could persist following exposure to a pressure.

A study by Boulcott & Howell (2011) on the effects of scallop dredging in rocky substrata suggested that associated epifaunal communities, such as bryozoans, hydroids, soft corals and sponges are removed by a passing scallop dredge and that damage to these communities is incremental. The study also recorded that mobile substrata present is likely to be moved and turned as a result of the passing dredge, leading to further damage to the epifaunal communities. The cumulative impacts of mobile substrata are likely to have a great significance for the CR.LCR.BrAs.AmenCio.Bri biotope, which is characterized by occurring on mixed substrata.

Encrusting and colonial organisms such as coralline crusts, sponges and bryozoans (including *Parasmittina trispinosa*), that occur in CR.MCR.EcCr.CarSp.Bri, may have good regenerative abilities. Veale *et al.* (2000) reported that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort. Both *Ciona intestinalis* and *Ascidia mentula*, found in CR.LCR.BrAs.AmenCio.Bri, are large, emergent, sessile ascidians, and physical disturbance is likely to cause damage with mortality likely. However, *Ascidia spp*. have been shown to become more abundant following disturbance events (Bradshaw *et al*., 2000); likely as a result of the rapid recruitment of these species.

Sensitivity assessment. Epifaunal species and communities are considered to be amongst the most vulnerable to bottom gears (Jennings & Kaiser, 1998) and the impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on the evidence, resistance to a single abrasion event is assessed as '**Low'** and resilience as **'Medium'**, so that sensitivity is assessed as '**Medium**'. Resistance and resilience will be lower (and hence sensitivity greater) to repeated abrasion events.

Penetration or disturbance of the substratum subsurface	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The species characterizing these biotopes are epifaunal occurring on rock which is resistant to sub-surface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure. '**Not Relevant'.**

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

Circalittoral rock habitats are characterized by animal dominated communities (Connor *et al*., 2004). *Ophiothrix fragilis*, *Ophiocomina nigra* and *Ophiura albida* are passive suspension feeders and a significant supply of suspended organic material is needed to meet the energetic costs of the great numbers of individuals in a brittlestar bed. Brittlestar beds occur in a variety of water flow regimes from sea lochs to more energetic coastal sites (Connor *et al*., 2004) so are likely to tolerate a variety of different suspended sediment concentrations. For example, dense britlestar beds occur in the Dover Straits, where the concentration of suspended particles in the water column changes between 18-32 mg/l annually (Davoult & Gounin, 1995). Although some brittlestar species are able to perceive differences in light and dark, visual perception is limited (Tillin & Tyler-Walters, 2014) and brittlestars are unlikely to be directly affected by changes in light resulting from a change in turbidity and suspended solids.

However, local increases in turbidity in waters previously within the photic zone, may alter local abundances of phytoplankton and surface diatoms and the zooplankton and other small invertebrates that feed on them. Davoult & Gounin (1995) found that the growth rate of *Ophiothrix* in the Dover Strait was maximal in April/May, coinciding with the spring phytoplankton bloom, which suggests that an increase in suspended solids and resulting increase in turbidity may indirectly reduce feeding efficiency in brittlestars. Nonetheless, since phytoplankton may arrive from distant sources and brittlestars may also feed on organic detritus any effects are expected to be small. Additionally, *Ophiothrix fragilis* has a low respiration rate and can tolerate considerable loss of body mass during reproductive periods (Davoult *et al*., 1990) suggesting that this species may tolerate feeding restrictions.

Other species occurring in the biotopes CR.MCR.EcCr.CarSp.Bri and CR.LCR.BrAs.AmenCio.Bri, such as hydroids, bryozoans, *Parasmittina trispinosa* and *Caryophillya smithii*, and *Ascidia mentula* and *Ciona intestinalis*, respectively, are suspension feeders and may benefit from an increase in suspended organic matter. Corals such as *Caryophillya smithii* have cilia on their tentacles capable of clearing silt (K. Hiscock, *pers. obs.*; cited in Hiscock, 2000) and Hiscock and Howlett (1976) found higher densities of *Caryophyllia smithii* in turbid waters which limited the growth of kelps. CR.LCR.BrAs.AmenCio.Bri often has a silty appearance (Connor *et al.*, 2004), so *Ascidia mentula* and *Ciona intestinalis* are likely to be tolerant of an increase in suspended sediment and may have adapted mechanisms to prevent blocking of feeding apertures (Naranjo *et al.*, 1996).

Coralline algae, especially the crustose forms that are relevant for biotope CR.MCR.EcCr.CarSp.Bri, are thought to be resistant of sediment scour (Littler & Kauker, 1984), so any resulting sediment scour resulting from an increase in suspended sediments will probably not adversely affect the coralline crusts at the benchmark level. A change in light resulting from a turbidity change is also unlikely to negatively affect coralline crusts as these are often found in areas with reduced light penetration (Dethier, 1994).

Sensitivity Assessment: The evidence presented suggests that an increase in suspended organic matter may be beneficial by providing increased food material while a decrease in suspended sediment may reduce food supplies to brittlestar beds. Additionally, increases in suspended solids that involve increase of inorganic particles may interfere with the feeding of brittlestars (Aronson, 1992 cited in Hughes, 1998b), particularly in non-current swept areas. However, the biotopes occur in a wide range of conditions and are likely to be adapted to respond to changes in suspended solids at the pressure benchmark and the overall species richness in the biotopes is not likely to change. Resistance is therefore assessed as **'High'** and resilience as '**High'**, so the biotope is assessed as '**Not Sensitive'** to a change in turbidity at the pressure benchmark.

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

Increased siltation on rock biotopes is likely to lead to a decrease in diversity. Material in suspension can affect the efficiency of filter and suspension feeding (Sherk & Cronin, 1970; Morton, 1976). Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates. Dense beds of brittlestars tend not to persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer, 1962 cited in Aronson, 1992). Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively suggested it was due to increased sedimentation caused by the localised dumping of construction materials (Aronson, 1989).

Species such as the soft coral *Alcyonium digitatum* that project above the substratum may not be completely covered with sediment but feeding structures may become clogged. Smaller colonies may be smothered, impairing respiration, and hence adversely affected. Encrusting species (e.g encrusting sponges, and bryozoans such as *Parasmittina trispinosa*) are more likely to be completely covered and will probably die (Jackson & Hiscock, 2008). However encrusting corallines and encrusting bryozoans have been reported to survive being overgrown by other species (Gordon, 1972; Sebens, 1985; Todd &Turner, 1988; cited in Tyler-Walters, 2002). The solitary ascidians *Ciona intestinalis* and *Ascidia mentula* are also attached, but frequently inhabit vertical surfaces (Jackson, 2008), so smothering with 5 cm of sediment is likely to only affect a small proportion of the population.

Caryophyllia smithii is small and sessile and would therefore likely be unable to avoid being inundated in a 'light' sedimentation event. Although, Bell & Turner (2000) reported *Caryophyllia smithii* was abundant at sites of 'moderate' sedimentation (7mm ± 0.5mm) in Lough Hyne, a light deposition of 5 cm of sediment is likely to adversely affect this cup coral.

In areas of high water flow dispersion of fine sediments may be rapid and this could mitigate the magnitude of this pressure by reducing the time exposed. This would likely be the case in the medium energy biotopes CR.MCR.EcCr.CarSp.Bri and CR.MCR.EcCr.FaAlCr.Bri, where 'light' deposition of sediments is likely to be cleared in a few tidal cycles. On the other hand, in the low energy biotope CR.LCR.BrAs.AmenCio.Bri, deposited sediment is likely to persist for a longer period, resulting in aggravated impacts on the biotopes' communities.

In exposed situations suspended material can cause scour, but this is normally a result of the temporary resuspension of relatively coarse bottom material rather than of fine material in long-term suspension.

Sensitivity assessment. This pressure is not considered to alter the physical reef habitat but there may be effects on the biological community. Habitat resistance is assessed as '**Low**' given that the key characterizing species of brittlestars are likely to be affected by a single discrete event of light deposition of fine materials that is not removed in the short-term by water movement. Resilience is likely to be '**Medium**' and the habitat sensitivity is assessed as '**Medium**'.

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

Overall, the effect of increased siltation on rock biotopes is likely to lead to a decrease in diversity. Material in suspension can affect the efficiency of filter feeding (Sherk & Cronin, 1970; Morton, 1976). Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates. Dense beds of brittlestars tend not to persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer, 1962 cited in Aronson, 1992). Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively suggested it was due to increased sedimentation caused by the localised dumping of construction materials (Aronson, 1989).

Species such as the soft coral *Alcyonium digitatum* that project above the substratum may not be completely covered with sediment but feeding structures may become clogged. Smaller colonies may be smothered, impairing respiration, and hence adversely affected.

Other more low lying or encrusting species (encrusting sponges, and bryozoans such as *Parasmittina trispinosa* are more likely to be completely covered and will probably die (Jackson & Hiscock, 2008). However encrusting corallines and encrusting bryozoans have been reported to survive being overgrown by other species (Gordon, 1972; Sebens, 1985; Todd & Turner, 1988 cited in Tyler-Walters, 2002). The solitary ascidians *Ciona intestinalis* and *Ascidia mentula* are also attached to isolated rocks and boulders, so the heights at which they occur may result in not all the population being affected by smothering with 30 cm of sediment.

Caryophyllia smithii is small and sessile and would therefore likely be unable to avoid and be inundated in a 'heavy' sedimentation event. Although, Bell & Turner (2000) reported *Caryophyllia smithii* was abundant at sites of 'moderate' sedimentation (7mm ± 0.5mm) in Lough Hyne, a heavy deposition of 30 cm of sediment is likely to adversely affect this cup coral.

In areas of high water flow dispersion of fine sediments may be rapid and this could mitigate the magnitude of this pressure by reducing the time exposed. This would likely be the case in the medium energy biotopes CR.MCR.EcCr.CarSp.Bri and CR.MCR.EcCr.FaAlCr.Bri, where 'heavy' deposition of sediments is likely to be cleared in several tidal cycles. On the other hand, in the low energy biotope CR.LCR.BrAs.AmenCio.Bri, deposited sediment is likely to persist for a longer period, resulting in aggravated impacts on the biotopes' communities.

In exposed situations suspended material can cause scour, but this is normally a result of the temporary re-suspension of relatively coarse bottom material rather than of fine material in long-term suspension.

Sensitivity assessment. This pressure is not considered to alter the physical reef habitat but there may be effects on the biological community. The brittlestars forming the dense beds characterizing these biotopes are likely to be adversely affected by the smothering effect of a 'heavy' deposition of 30 cm of sediment in a single discrete event. Other small suspension feeders, encrusting species and cup-corals may also be smothered resulting in a decrease in species diversity, depending on the time taken for the deposited sediment to be removed by water flow. Habitat resistance is assessed as '**Low'** for CR.MCR.EcCr.CarSp.Bri and CR.MCR.EcCr.FaAlCr.Bri, and '**None**' for CR.LCR.BrAs.AmenCio.Bri, based on how quickly the sediment deposited would be removed by water movement. Recovery is probably '**Medium**' and the habitats sensitivity is assessed as '**Medium'**.

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

Not assessed.

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

'**No Evidence'** 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

There is little known about the effects of underwater sound on marine invertebrates. Although there are no records of brittlestars reacting to noise, sound vibrations may trigger some response. However, at the level of the benchmark the biotopes are not likely to be sensitive to noise pollution. For example, brittlestar beds have been recorded from Kinsale Harbour (Hughes, 1998b) on the south coast of Ireland where there is likely to be noise disturbance from passing boat traffic.

Sensitivity assessment: There is not enough evidence to assess this pressure.

Introduction of light or shading	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

CR.MCR.EcCr.CarSp.Bri, CR.MCR.EcCr.FaAlCr.Bri and CR.LCR.BrAs.AmenCio.Bri are circalittoral biotopes (Connor *et al.*, 2004) and therefore, not directly dependent on sunlight. Although some brittlestar species are able to perceive differences in light and dark, visual perception is limited (Tillin & Tyler-Walters, 2014) and this suggests that the brittlestars are unlikely to be directly affected by change in light.

Sensitivity assessment. The biotopes are considered to have **'High**' resistance and, by default, '**High**' resilience and therefore is **'Not Sensitive'** to this pressure.

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' 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	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

Ophiothrix fragilis and other brittlestars and starfish are likely to have poor facility for visual perception and consequently are probably not sensitive to visual disturbance. Movement of a hand near to *Ophiothrix fragilis*, for example, elicits no escape response (Sköld, 1998). Although some other species, such as crabs and fish, may respond to visual disturbance such behaviour is not likely to have an impact on the nature and function of a brittlestar bed so the biotopes are expected to be not sensitive to the factor. Therefore, this pressure is considered **'Not Relevant'.**

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 these biotopes are not cultivated or likely to be translocated. This pressure is therefore considered '**Not Relevant**'.

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

For biotopes CR.MCR.EcCr.CarSp.Bri and CR.MCR.EcCr.FaAlCr.Bri, no evidence on the presence of non-indigenous species or impacts of non-indigenous species was found. This pressure is therefore not assessed, based on '**No Evidence**'.

For biotope CR.LCR.BrAs.AmenCio. Bri, *Styela clava* was first recorded in the UK at Plymouth in 1952 (Eno *et al.*, 1997), and where *Styela clava* and *Ciona intestinalis* co-occur they may compete for space and food. However, the main characterizing feature of the biotope (the brittlestars) would be likely to remain un-altered, so this biotope is considered '**Not Sensitive'.**

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

Introduced organisms (especially parasites or pathogens) are a potential threat in all coastal ecosystems. So far, brittlestar beds have not been affected. Dense aggregations of brittlestars would offer ideal conditions for the rapid spread of pathogenic organisms or parasites, but so far no examples of this have been recorded. However, several examples are known of echinoderm populations that have been massively reduced by sudden outbreaks of epidemic disease. Cases include the mass mortality of the sea urchin *Diadema antillarum* throughout the Caribbean as a result of infection by a water-borne pathogen (Lessios, 1988), and the decimation of urchin populations in the North Atlantic by parasitic amoebae and nematodes (Hagen, 1997). Epidemic disease should therefore be considered as having the potential to significantly affect populations of bed-forming brittlestars (Hughes, 1998b), as even widespread and abundant species can be vulnerable.

Lynch *et al*. (2007) investigated the possible role of benthic macroinvertebrates and zooplankton in the life cycle of *Bonamia ostrea*, a parasite the European flat oyster *Ostrea edulis*. Their laboratory studies found that the brittlestar *Ophiothrix fragilis* was a passive carrier of the parasite but is not infected. Brittlestar mortality in their treatments was not explained, and it was uncertain if parasite infection was to blame. However, they found where the oysters co-habited with the brittlestars, oyster infection by the parasite was lower. It is, however, unlikely that the oyster-specific parasite would be responsible for the brittlestar mortalities recorded (Lynch *et al*., 2007).

The parasite *Lankesteria ascidiae* is the only pathogen targeting any of the characterizing species in these biotopes, attacking the digestive tubes and causing 'long faeces syndrome' in *Ciona intestinalis* (although it has also been recorded in other species), and is therefore relevant for biotope CR.LCR.BrAs.AmenCio.Bri. Mortality occurs in severely affected individuals within about a week following first symptoms (Mita *et al*., 2012).

Sensitivity assessment. The evidence suggests that brittlestars may be exposed to pathogens, but that no mortality has been reported. Therefore brittlestar beds probably have '**High**' resistance to this pressure. By default resilience is assessed as '**High**' and the biotopes are classed as '**Not sensitive**'.

Removal of target 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

Brittlestar beds are currently not targeted by commercial fisheries and hence not directly affected by this pressure (Tillin & Tyler-Walters, 2014). This pressure is therefore considered '**Not Relevant**'.

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

Fisheries tend to avoid brittlestar beds since the animals clog nets (Jones *et al*., 2000). However, brittlestars may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration pressures. The sensitivity assessment for this pressure considers any biological and ecological effects resulting from the removal of non-target species.

Although several species of brittlestar (including *Ophiocomina nigra*) were reported to have increased in abundance in trawled areas, Bradshaw *et al.* (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long term in areas subject to scallop dredging. The bed may contract in size as individual brittlestars move to re-establish contact with neighbours or the number of low density patches could increase. If water currents were very strong some animals may be washed away as the support provided by other individuals in dense aggregations decreases. In addition, commercial fisheries may discard damaged or dead non-target species. This could result in increased available food supply to scavenging brittlestars but may also attract mobile predators and scavengers including fish and crustaceans to habitats supporting brittlestars, which may alter predation rates.

The remaining defining species in these biotopes, including the coralline crusts, *Caryophyllia smithii* and *Parasmittina trispinosa* for biotope CR.MCR.EcCr.CarSp.Bri, and *Ciona intestinalis* and *Ascidia mentula* for biotope CR.LCR.BrAs.AmenCio.Bri, are sessile and also likely to be incidentally removed as part of an extraction or fishing event.

Sensitivity assessment: Once extraction or fishing has stopped, brittlestars that remain in the bed are likely to be able to re-establish the density observed prior to the event. Based on the evidence presented, the resistance of these biotopes is considered to be '**Low**', with **'Medium'** resilience and therefore the biotopes are considered to have '**Medium**' sensitivity to this pressure.

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