Crepidula fornicata with ascidians and anenomes on infralittoral coarse mixed sediment

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

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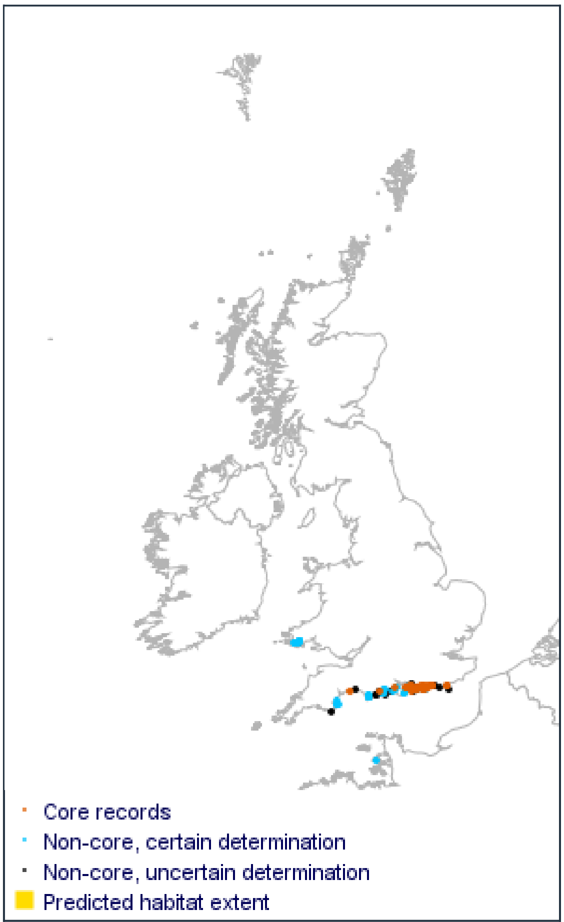

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by John Readman **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.431	*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment
JNCC 2015	SS.SMx.IMx.CreAsAn	*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment
JNCC 2004	SS.SMx.IMx.CreAsAn	*Crepidula fornicata* with ascidians and anemones on infralittoral coarse mixed sediment
1997 Biotope	SS.IMX.EstMx.CreAph	*Crepidula fornicata* and *Aphelochaeta marioni* in variable salinity infralittoral mixed sediment

Description

Medium-coarse sands with gravel, shells, pebbles and cobbles on moderately exposed coasts may support populations of the slipper limpet *Crepidula fornicata* with ascidians and anemones. *C.*

fornicata is common in this biotope though not as abundant as in the muddier estuarine biotope CreMed to which this is related. Anemones such as *Urticina felina* and*Alcyonium digitatum* and ascidians such as *Styela clava* are typically found in this biotope. Bryozoans such as *Flustra foliacea* are also found along with polychaetes such as *Lanice conchilega*. Little information is available with regard the infauna of this biotope but given the nature of the sediment the infaunal communities are liable to resemble those in biotopes from the SCS habitat complex. As with FluHyd this biotope could be considered a superficial or epibiotic overlay but more data is required to support this.

Depth range

-

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Both SS.SMx.IMx.CreAsAn and SS.SMx.SMxVS.CreMed are characterized by the presence of the invasive *Crepidula fornication* infralittoral sediment and generally occur on the southern coast of England.

SS.SMx.IMx.CreAsAn occurs on medium-coarse sands with gravel, shells, pebbles and cobbles on moderately exposed coasts. In addition to *Crepidula forincata*, a faunal community is present comprising ascidians (including *Styela clava*), anemones and bryozoans. Polychaetes may also be found, but little information is available regarding the infauna (Connor *et al*., 2004).

SS.SMx.SMxVS.CreMed is similar, but occurs in mixed muddy sediments estuarine conditions, subject to variable salinity. *Crepidula fornicata* tends to be found in greater abundances, the faunal community is less conspicuous and the polychaetes *Mediomastus fragilis* and *Aphelochaeta marioni* are considered characterizing (Connor *et al*., 2004).

This assessment focuses on the important characterizing *Crepidula fornicata* and the polychaetes *Mediomastus fragilis* and *Aphelochaeta marioni*. The assessments also take into consideration faunal communities including ascidians and anemones where appropriate.

Resilience and recovery rates of habitat

Crepidula fornicata is a protandrous hermaphrodite that starts its life as male and then, subsequently, may change sex and develop into a female. Although breeding can occur between February and October, peak reproduction occurs in May and June when 80-90% of females spawn. Most females spawn twice in a year and can lay ca 11,000 eggs at a time, contained in up to 50 egg capsules (Deslou-Paoli & Heral, 1986). Thain (1984) reported that, following incubation, ca 4,000 larvae were released per female. Incubation of the eggs takes 2-4 weeks followed by a planktotrophic larval phase lasting 4-5 weeks (Fretter & Graham, 1981; Thouzeau, 1991). Due to the length of the planktonic phase, the potential for dispersal is high. Recruitment is determined by the local hydrographic regime. For example, in sheltered bays the larvae may be entrapped and small scale eddies (e.g. over obstacles and inconsistencies in the surface of the substratum) may result in the concentration of larvae. The ability of *Crepidula fornicata* to disperse widely and colonize new areas is demonstrated by its spread through Europe following introduction from North America at the end of the 19th century (Fretter & Graham, 1981; Eno *et al*., 1997). The spat settle in isolation or on top of an established chain of *Crepidula fornicata*. *Crepidula fornicata* needs to be part of a chain in order to breed and, therefore, would be expected to settle preferentially where high densities of conspecifics already exist. High densities of suspension feeders and surface deposit feeders together with epibenthic predators and physical disturbance may result in a high post settlement mortality rate of larvae and juveniles (Olafsson *et al*., 1994). Males reach sexual maturity two months after settlement (Fretter & Graham, 1981). If a male develops directly into a female, sexual maturity may be reached in 10 months (Nelson *et al*., 1983). Immediately after settlement, juvenile *Crepidula fornicata* are capable of slow crawling and locate a suitable site for attachment and growth. This is either a stone or a chain of other *Crepidula fornicata* (conspecifics). The shell then grows to fit the substratum and consequently most animals are incapable of further movement at the age of about two years (Fretter & Graham, 1981). Cole & Hancock (1956) reported that following clearance of slipper limpets from oyster beds, populations took up to 10 years to regain pre-clearance levels. However, given the species' reproductive characteristics and invasive record, it is likely that in most situations, populations would recover within five years.

Aphelochaeta marioni has no pelagic phase in its lifecycle, and dispersal is limited to the slow burrowing of the adults and juveniles (Farke, 1979). The blow lug, *Arenicola marina*, has similar dispersal capabilities and its recoverability has been well studied. It is therefore a suitable species to act as a guide for the recoverability of infaunal polychaetes. Heavy commercial exploitation in Budle Bay in winter 1984 removed 4 million worms in 6 weeks, reducing the population from 40 to <1 per m^2. Recovery occurred within a few months by recolonization from surrounding sediment (Fowler, 1999). However, Cryer *et al.* (1987) reported no recovery for 6 months over summer after mortalities due to bait digging. Beukema (1995) noted that the lugworm stock recovered slowly after mechanical dredging, reaching its original level in at least three years. Fowler (1999) pointed out that recovery may take a long time on a small pocket beach with limited possibility of recolonization from surrounding areas. Therefore, if adjacent populations are available recovery will be rapid. However where the affected population is isolated or severely reduced, recovery may be extended.

The characterizing polychaete *Mediomastus fragilis* is opportunistic species (small size, rapid maturation and short lifespan of 1-2 years with production of large numbers of small propagules). It is likely to recolonize disturbed areas first, although the actual pattern will depend on recovery of the habitat, season of occurrence and other factors. Sardá *et al.* (1999) tracked annual cycles within a *Spisula* community in Bay of Blanes (north west Mediterranean sea, Spain) for 4 years. Macroinfaunal abundance peaked in spring, decreased sharply throughout the summer, with low density in autumn and winter. The observed trends were related to a number of species, including the characterizing *Mediomastus fragilis*. The *Spisula subtruncata* populations were dominated by juveniles, with high abundances in spring followed by declines in summer, with very few survivors 3 months after recruitment. In comparison, *Mediomastus fragilis* had spring population peaks but more individuals persisted throughout the year.

The majority of the other species in the biotope are relatively short-lived and highly fecund and will probably reach mature community population levels rapidly. For example, ascidians exhibit annual episodic recruitment and are likely to achieve mature populations very quickly where suitable substrata and hydrographic conditions exist. The rapid recoverability of estuarine soft sediment infauna was reported by Hall & Harding (1997). Following suction dredging which resulted in 50% reduction in number of individuals of infauna, populations recovered to pre-dredging levels within 56 days.

Both *Crepidula fornicata* and *Aphelochaeta marioni*, are tolerant of a wide range of environmental conditions. For example, they are euryhaline, are found on a variety of substrata and tolerate variations in turbidity. However, they both achieve peak abundances in areas of muddy or mixed muddy sediments such as occur in the hydrographic regime of sheltered bays and lower estuaries (Gibbs, 1969; De Montadouin & Sauriau, 1999). The distribution of the biotope is probably limited by the geographic range of *Crepidula fornicata*, which only occurs in the southern half of the British Isles.

Resilience assessment

Crepidula fornicata is an invasive, highly fecund species which matures in 2-10 months. Larvae have a long pelagic phase (Fretter & Graham, 1981; Thouzeau, 1991) and the potential for dispersal is high. Recruitment is likely to very rapid, however some studies have suggested that recover following almost complete removal may be longer, taking up to 10 years (Beukema (1995). The polychaetes are likely to be opportunistic and recover rapidly from significant mortality.

Resilience is therefore likely to be '**High**' for most levels of perturbation, although a resilience of '**Medium**' (recovery in 2-10 years) was recorded for resistances of 'None', based on evidence following clearance of *Crepidula fornicata*.

Hydrological Pressures

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

The characterizing species in the biotope occur over a very wide geographic range. *Crepidula fornicata* has a southerly distribution in the British Isles (NBN, 2015) and is found in the Mediterranean (Sciberras & Schembri, 2007). On the east coast of the Americas, *Crepidula fornicata* is found as far south as Mexico and, therefore, must be able to tolerate higher temperatures than it experiences in northern Europe. The effect of temperature on larval development was investigated by Lucas & Costlow (1979). Larvae were found to tolerate daily temperature cycles of 5°C between 15°C and 30°C with little mortality. Over a 12 day period there was 0% mortality at 30°C but 100% mortality occurred by day 6 at 35°C.

Aphelochaeta marioni has been recorded from the Mediterranean Sea and Indian Ocean (Hartmann-Schröder, 1974; Rogall, 1977; both cited in Farke, 1979) and therefore must also be capable of tolerating higher temperatures than experienced in the British Isles. *Mediomastus fragilis* has been recorded throughout the British Isles (NBN, 2015) and in the Mediterranean (Faulwetter, 2010). However, the polychaetes live infaunally and are likely to be insulated from short-term temperature change.

Sensitivity assessment

The important characterizing species occur in the Mediterranean and are probably resistant to an increase at the benchmark level. Resistance has been recorded as '**High**', resilience as '**High'** and the biotope is '**Not sensitive**' at the benchmark level.

	Resistance	Resilience	Sensitivity
Temperature decrease (local)	Low Q: Medium A: Medium C: Medium	High Q: High A: Medium C: Medium	Low Q: Medium A: Medium C: Medium

The distribution of *Crepidula fornicata* is generally limited to the south coast of England (NBN, 2015). During the severe winter of 1962-63 the British populations of marine invertebrates were subjected to an acute decrease in temperatures. Waugh (1964) recorded 25% mortality of *Crepidula fornicata* from the south coast and east coast of England where the recorded temperatures were 5-6°C and 3-4°C respectively below normal for a period of two months. *Crepidula fornicata populations* in the Wadden Sea were strongly affected by cold winters, Thieltges *et al.* (2004) reported that mortality over two winters amounted to 56–64% with up to 97% on single mussel beds, in contrast to 11–14% yearly mortality in areas without frost in southern Europe. Thieltges *et al.*(2004) also found low larval abundances after an exceptionally severe winter and suggested that winter mortality was the main limiting factor for population increase in the study area.

The characterizing polychaetes are infauna, which would afford them some protection in the event of a short-term change in temperature. *Aphelochaeta marioni* occurs throughout the British Isles (NBN, 2015) and is likely to tolerant decreases in temperature at the benchmark level. For example, in the Wadden Sea, the population was apparently unaffected by a short period of severe frost in I973 (Farke, 1979).

During the cold winter of 1962-63, infaunal species (e.g. *Corophium volutator*, *Harmothoe impar*, *Nephtys hombergi*) were largely unaffected (Crisp, 1964a). Species richness in the biotope is, therefore, expected to show a minor decline.

Sensitivity assessment

Evidence suggests that *Crepidula fornicata* is susceptible to cold temperatures and this is likely to a factor in limiting distribution of the species Thieltges *et al.*(2004). Resistance is likely to be **'Low'**, resilience as **'High'** and the sensitivity as **'Low'**.

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

SS.SMx.SMxVS.CreMed occurs in variable salinity and SS.SMx.IMx.CreAsAn occurs in full salinity. An increase at the benchmark level would result in hypersalinity (>40 ppt) which is likely to cause mortality. However, '**No evidence'** was found for the characterizing hypersaline conditions.

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

Despite being described as euryhaline (Blanchard, 1997), *Crepidula fornicata* is principally a marine organism and a decrease in salinity to levels below 18 psu would be likely to cause water balance stress and therefore impair growth and reproduction (Raiment, 2008). Environmental fluctuations in salinity are only likely to affect the surface of the sediment, and not deeper organisms, since the interstital or burrow water is little affected. Polychaetes are infaunal and are likely to have some resistance to decreases in salinity.

Aphelochaeta marioni, has been recorded from brackish inland waters in the southern Netherlands with a salinity of 16 psu, but not in areas permanently exposed to lower salinities (Wolff, 1973). It also penetrates into areas exposed to salinities as low as 4 psu for short periods at low tide when freshwater discharge from rivers is high (Farke, 1979).

Whilst *Styela clava* is capable of surviving short-term hyposalinity down to 8‰, it is suggested that this is due to closing its siphons (Sims, 1984), however, the species is generally not found in areas with estuarine conditions (Lützen, 1998). Sims (1984) reported that *Styela clava* has limited osmoregulatory capability in hyposaline media (poor vital functions and complete cessation of siphonal responses at 26.5‰). Kelly (1974) observed dramatic reduction in population density following heavy rainfall during the winter of 1972/1973 in Newport Bay, California.

Lützen & Sorensen (1993) exposed *Styela clava* to a gradually salinity decrease from 31‰ to 18‰ over 40 days, with 17 of 24 animals having survived. A decrease to 16‰ over 50 days resulted in mortality in 6 of 12 specimens. Kashenko (1996) reported that larvae of *Styela clava* from the Sea of Japan were able to complete metamorphosis at salinities ranging from 32‰ to 20‰, but that salinities below 18‰ were deleterious.

Ryland (1970) stated that, with a few exceptions, the Gymnolaemata were fairly stenohaline and restricted to full salinity (30-35 ppt), noting that reduced salinities result in an impoverished bryozoan fauna. *Flustra foliacea* appears to be restricted to areas with high salinity (Tyler-Walters & Ballerstedt 2007; Budd 2008). Dyrynda (1994) noted that *Flustra foliacea* and *Alcyonidium diaphanum* were probably restricted to the vicinity of the Poole Harbour entrance by their intolerance to reduced salinity. Although protected from extreme changes in salinity due to their subtidal habitat, severe hyposaline conditions could adversely affect *Flustra foliacea* colonies.

Sensitivity assessment: SS.SMx.IMx.CreAsAn occurs in full salinity and SS.SMx.SMxVS.CreMed occurs in variable salinity. Decrease at the benchmark level to 'reduced' may cause mortality among the characterizing species. It should be noted that a decrease from variable (18 -40 ppt) to reduced (18 – 30 ppt) does not result in a lower range limit. A change from full (CreAsAn) to variable (CreMed) would probably reduce the abundance of ascidians and anemones, so that CreAsAn would come to resemble CreMed. Resistance is **'Medium'**, resilience is **'High'** and sensitivity is **'Low'** at the benchmark level.

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

This biotope occurs in wave protected areas where water flow is typically moderately strong. If water flow was to increase to strong or very strong, it is likely that physical damage to the bed would occur. Erosion and re-suspension of the sediment could result in a change in substrata. Increased flow over the bed could potentially remover lighter sediment fractions, leaving only coarser sediment, boulders and bedrock.

Therefore, the infaunal species would be outside their habitat preferences and some mortality would be likely to occur. Additionally, the consequent lack of deposition of particulate matter at the sediment surface could reduce food availability for deposit feeders. The resultant energetic cost over one year could also result in some mortality.

Crepidula fornicata is a cosmopolitan species but is found in greatest numbers in wave protected areas (Blanchard, 1997) and has only been recorded in biotopes that occur in moderately strong or weaker water flow (Connor *et al.*, 2004). An increase in water flow outside the species' habitat preferences may cause mortality through interference with feeding and/or respiration.

Sensitivity assessment. An increase in water flow rate may physically disturb the bed, where the change is outside the biotopes normal range of water flow. Examples of the habitat at the limits of the range of water flow are likely to be most sensitive to change. However, a change in water flow of 0.1-0.2 m/s, is unlikely to affect adversely the biotope. Therefore, resistance and resilience are '**High**' and the biotope is '**Not sensitive**' at the benchmark level.

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

This biotope can occur in the 0-5 m range. *Crepidula fornicata* may be able to survive in the intertidal zone without resort to anaerobiosis. Between 70 and 90% of the minimum aquatic oxygen requirements may be met by aerial gas exchange (Newell & Kofoed, 1977). The infaunal polychaetes would have some resistance to emergence, however other species composing the faunal turf are restricted to the sublittoral and emergence would likely cause significant damage to the community.

Sensitivity assessment: Whilst *Crepidula fornicata* would probably be tolerant of short-term emergence, the faunal turf comprising sublittoral ascidians and bryozoans would suffer mortality and resistance is, therefore, assessed as **'Low'**. Following return to normal conditions, the faunal turf species are likely to recover rapidly and resilience is therefore '**High**', with '**Low**' sensitivity.

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

SS.SMx.SMxVS.CreMed occurs in sheltered or extremely sheltered conditions, whereas SS.SMx.IMx.CreAsAn occurs in moderately exposed conditions (Connor *et al*., 2004). A significant increase in wave exposure could erode fine sediments (Hiscock, 1983), resulting in the likely reduction of the habitat of the infaunal species and a decrease in food availability for deposit feeders. Gravel and cobbles are likely to be moved by strong wave action resulting in damage and displacement of epifauna. *Crepidula fornicata* has been reported washed up on the shore following storms (Hayward & Ryland, 1995b). Species may be damaged or dislodged by scouring from sand and gravel mobilized by increased wave action. Furthermore, strong wave action is likely to cause damage or withdrawal of delicate feeding and respiration structures of species within the biotope resulting in loss of feeding opportunities and compromised growth.

Evidence for polychaetes is limited for the effects of wave exposure changes. Increased wave action results in increased water flow in the shallow subtidal. Wave mediated water flow tends to be oscillatory, i.e. moves back and forth (Hiscock, 1983), and may result in dislodgement or removal of individuals. The infaunal nature of the polychaetes is likely to provide some resistance to increases in wave exposure (Coosen *et al*., 1994), but if the change was significant enough to modify the sediment, it would result in a change in the infaunal community.

Sensitivity assessment: Whilst significant increases in wave exposure (e.g. storms) have been linked with displacement of *Crepidula fornicata*, an increase in wave exposure at the benchmark level (3-5% change in significant wave height) is unlikely to result in mortality and resistance is therefore **'High'**, resilience is **'High'** and the biotope is assessed as '**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

As with synthetic chemicals, heavy metals tend to accumulate in the fine sediments (Elliot *et al*., 1998). The intolerance of the characterizing species, *Crepidula fornicata*, has been well studied. In the Fal Estuary, *Crepidula fornicata* does occur in the Carrick Roads, an area where creek water polluted with heavy metals mixes with the open ocean (Bryan & Gibbs, 1983). In this area, concentrations of silver, cadmium, copper, lead and zinc were found to be higher than in 'control' estuaries (Bryan & Gibbs, 1983). This suggests *that Crepidula fornicata* is at least partially tolerant to heavy metal contamination. Laboratory trials have revealed specific responses to heavy metals. Thain (1984) investigated the effects of exposure to mercury. Half the adults and larvae died after 96 hours following exposure to 330 and 60 µg/l respectively. Furthermore, sub-lethal concentrations of mercury were shown to impair growth and condition of young adult *Crepidula fornicata* and impair reproductive capacity at 0.25 µg/l. Nelson *et al.* (1983) investigated the effects of exposure to silver. Reproductive output was found to be impaired following exposure to the highest concentration of silver nitrate (10 µg/l) for 24 months. The evidence suggests that high concentrations of heavy metals will cause mortality in *Crepidula fornicata*. However, lower concentrations, which could realistically occur *in situ* impair growth, condition and reproductive output and will therefore affect the long-term health of the population.

Evidence suggests that the polychaetes present in this biotope, are more tolerant of heavy metal contamination. *Aphelochaeta marioni* occurs in the heavily polluted Restronguet Creek (Bryan & Gibbs, 1983) and has also been reported to accumulate arsenic (Gibbs *et al.*, 1983).

However, this pressure is **Not assessed** but evidence is presented where available.

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

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

Oil spills resulting from tanker accidents can cause large-scale deterioration of communities in shallow subtidal sedimentary systems. The majority of benthic species often suffer high mortality, allowing a few tolerant opportunistic species to proliferate. For example, after the *Florida* spill of 1969 in Massachusetts, the entire benthic fauna was eradicated immediately following the spill and populations of the opportunistic polychaete *Capitella capitata* increased to abundances of over 200,000/m^2 (Sanders, 1978).

No evidence could be found for the effect of hydrocarbons on *Crepidula fornicata* specifically. However, inferences can be drawn from other gastropods. Following the *Torrey Canyon* oil spill in 1967, total mortality of 3 *Patella* species was reported after one month of oil coming ashore at Porthleven reef (Smith, 1968). Other gastropod mortalities included *Nucella lapillus*, *Nassarius incrassatus* and *Gibbula* sp. Based on the evidence for other gartopods, *Crepidula fornicata* would probably suffer high mortality when exposed to hydrocarbon contamination.

Aphelochaeta marioni, however, has been reported to be highly resistant to oil spills, probably because the feeding tentacles are protected by a heavy secretion of mucus (Suchanek, 1993). This is supported by observations of the species following the *Amoco Cadiz* oil spill in March, 1978 (Dauvin, 1982, 2000). Prior to the spill, *Aphelochaeta marioni* was present in very low numbers in the Bay of Morlaix, western English Channel. Following the spill, the level of hydrocarbons in the sediment increased from 10 mg/kg dry sediment to 1443 mg/kg dry sediment 6 months afterwards. In the same period, *Aphelochaeta marioni* increased in abundance to a mean of 76 individuals/m^2, which placed it among the top five dominant species in the faunal assemblage. Six years later, abundance of *Aphelochaeta marioni* began to decline, accompanied by gradual decontamination of the sediments. Borja *et al.* (2000) recorded the relative sensitivity of *Mediomastus fragilis* as an ABMI Ecological Group III species ‘tolerates disturbance and excess organic content’.

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.

Toxins, including synthetic chemicals such as dieldrin and poly-chlorinated biphenyls, tend to accumulate in low energy areas such as estuaries where the IMX.CreAph biotope occurs. Dispersion is low in these areas and the fine substrata act as a sink, retaining toxins for long periods of time (see review by Elliot *et al.*, 1998). Therefore, the species which live infaunally in fine sediments, such as polychaetes, would be expected to be most vulnerable. Collier & Pinn (1998) investigated the effect on the benthos of ivermectin, a feed additive treatment for infestations of sea-lice on farmed salmonids. The polychaete *Hediste diversicolor* was particularly susceptible, exhibiting 100% mortality within 14 days when exposed to 8 mg/m^2 of ivermectin in a microcosm. *Arenicola marina* was also intolerant of ivermectin through the ingestion of contaminated sediment (Thain *et al.*, 1997; cited in Collier & Pinn, 1998) and it was suggested that deposit feeding was an important route for exposure to toxins. Beaumont *et al.* (1989) investigated the effects of tri-butyl tin (TBT) on benthic organisms. At concentrations of 1-3 µg/l there was no significant effect on the abundance of *Hediste diversicolor* or *Cirratulus cirratus* after 9 weeks in a microcosm. However, no juvenile polychaetes were retrieved from the substratum and hence there is some evidence that TBT had an effect on the larval and/or juvenile stages of these polychaetes.

No evidence was found on the effects of synthetic compounds specifically on *Crepidula fornicata*. However, there is evidence concerning effects on other molluscs. For example, the effect of TBT from anti-fouling paints on gastropods is very well documented. Imposex, female mortality and the subsequent decline in population, has been described in *Nucella lapillus* (e.g. Bryan *et al.*, 1986), *Littorina littorea* (Bauer *et al.*, 1995), *Ilyanassa obsoleta* and *Urosalpinx cinerea* (Matthiessen & Gibbs, 1998). Limpets (Patellidae) are extremely intolerant of aromatic solvent based dispersants used in oil spill clean-up. Following the clean-up response to the *Torrey Canyon* oil, almost all limpets were killed in areas close to dispersant spraying. Viscous oil will not be readily drawn in under the edge of the shell by ciliary currents in the mantle cavity, whereas detergent, alone or diluted in seawater, would creep in much more readily and be liable to kill the limpet (Smith, 1968). For example, a concentration of 5 ppm of dispersant killed half the patellid limpets tested in 24 hours (Southward & Southward, 1978; Hawkins & Southward, 1992).

Radionuclide contamination	High Q: Medium A: Low C: Low	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: Low

Information on intolerance to nuclear radiation is generally scarce. Greenberber *et al.* (1986) exposed larval *Crepidula fornicata* to doses of X-ray radiation between 500 and 20,000 Rad. After 20 days, there was a dose dependent decrease in larval shell growth rate and a significant increase in larval mortality following doses above 2000 Rad (equivalent to 20 Gy). These levels of radiation are extremely high compared to background levels in the environment. For reference, Polykarpov (1998) (cited in Cole *et al.*, 1999) describes the natural levels of background radiation being equivalent to a dose of 0.005 Gy per year (equivalent to 0.5 Rad per year). Hence, high doses of radiation have been shown to significantly increase mortality while lower levels have sub-lethal effects on growth and reproduction. There is little evidence concerning other species in the biotope.

Sensitivity assessment. Evidence at the benchmark level is unavailable, however, *Crepidula* *fornicata* mortality at high levels of radiation has been reported. Nevertheless, mortality as the benchmark level is unlikely and resistance is therefore **'High'**, resilience is **'High'** and the biotope is **'Not sensitive'**.

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

In general, respiration in most marine invertebrates does not appear to be significantly affected until extremely low concentrations are reached. For many benthic invertebrates this concentration is about 2 ml/l (Herreid, 1980; Rosenberg *et al.*, 1991; Diaz & Rosenberg, 1995). Cole *et al.* (1999) suggest possible adverse effects on marine species below 4 mg/l and probable adverse effects below 2 mg/l.

No direct evidence was found for specific effects of reduced oxygenation on adult *Crepidula fornicata*. Brante *et al*. (2009) reported that whilst hypoxic conditions affected the growth rate of embryonic *Crepidula fornicata* during development, survival was not affected. Borja *et al.* (2000) recorded the relative sensitivity of both *Mediomastus fragilis* and *Crepidula fornicata* as ABMI Ecological Group III species that 'tolerate disturbance and excess organic content'.

Infaunal species which typically tolerate lower oxygen tensions than occur in the water column are likely to be less intolerant of reductions in dissolved oxygen. For example, Broom *et al.* (1991) recorded that *Aphelochaeta marioni* characterized the faunal assemblage of very poorly oxygenated mud in the Severn Estuary.

Sensitivity assessment. The characterizing species are likely to be resistant to hypoxic events. Resilience is therefore '**High**', recoverability is '**High**' and the biotope is '**Not sensitive**' at the benchmark level.

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

Nutrient enrichment can lead to significant shifts in community composition in sedimentary habitats. The intolerance of the characterizing species *Aphelochaeta marioni* is difficult to ascertain from the available evidence. Raman & Ganapati (1983) presented evidence that *Aphelochaeta marioni* is not tolerant of eutrophication. However, nutrient enrichment would lead to increased food availability, the species is tolerant of low oxygen conditions (Broom *et al.*, 1991), and has been recorded as proliferating following an oil spill which resulted in eutrophic conditions (Dauvin 1982, 2000). No information was found for the intolerance of *Crepidula fornicata* to nutrient enrichment.

Nevertheless, this biotope is considered to be **'Not sensitive'** at the pressure benchmark, that assumes compliance with good status as defined by the WFD.

Organic enrichment

Resistance	Resilience	Sensitivity
High	High	Not sensitive
Q: Medium A: Medium C: Medium	Q: High A: High C: High	Q: Medium A: Medium C: Medium

Whilst Raman & Ganapati (1983) presented evidence that *Aphelochaeta marioni* is not tolerant of eutrophication, organic enrichment would lead to increased food availability and the species is tolerant of low oxygen conditions (Broom et al., 1991). It has also been recorded as proliferating following an oil spill which resulted in eutrophic conditions (Dauvin, 1982; 2000)

Borja *et al.* (2000) recorded the relative sensitivity of both *Mediomastus fragilis* and *Crepidula fornicata* as ABMI Ecological Group III species that 'tolerate disturbance and excess organic content'. Resistance is, therefore, assessed as **'High'**, resilience as **'High'** and the biotope is **'Not sensitive'** at the benchmark level.

Physical Pressures

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

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

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

If sediment were replaced with rock or artificial substrata, this would represent a fundamental change to the biotope with reclassification necessary. Change from a mixed sediment substrata to rock would also result in loss of the infaunal component. Resistance to the pressure is considered '**None**', and resilience '**Very Low**'. Sensitivity has been assessed as '**High**'

	Resistance	Resilience	Sensitivity
Physical change (to another sediment type)	Low	Very Low	High
	Q: Medium A: Medium C: Medium	Q: High A: High C: High	Q: Medium A: Medium C: Medium

A change in one Folk class is considered to relate to a change in classification to adjacent categories in the modified Folk triangle (Long, 2006). SS.SMx.IMx.CreAsAn occurs on medium coarse sands and SS.SMx.SMxVS.CreMed occurs on Mixed muddy sediment.

Sediment type is a key factor structuring the biological assemblage present in the biotope. Surveys over sediment gradients and before-and-after impact studies from aggregate extraction sites where sediments have been altered indicate patterns in change. The biotope classification (JNCC, 2015) provides information on the sediment types where biotopes are found and indicate likely patterns in change if the sediment were to alter. Long-term alteration of sediment type to finer more unstable sediments was observed six years after aggregate dredging at moderate energy sites (Boyd *et al.*, 2005).

Differences in biotope assemblages in areas of different sediment type are likely to be driven by pre and post recruitment processes. Sediment selectivity by larvae will influence levels of settlement and distribution patterns. Snelgrove *et al.* (1999) demonstrated that capitellid polychaetes selected muddy sand over coarse sand, regardless of site. Both larvae selected sediments typical of adult habitats, however, some species were nonselective (Snelgrove *et al.*, 1999) and presumably in unfavourable habitats post recruitment, mortality will result for species that occur in a restricted range of habitats.

Sensitivity assessment: While the epifauna are unlikely to be affected, change in sediment at the benchmark level, (e.g. to coarser sediments) is likely to impact the infaunal polychaete community. Resistance is assessed as **'Low'**, as resilience is **Very low** (the pressure is a permanent change), sensitivity is, therefore, **High.**

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

Sedimentary communities are likely to be highly intolerant of substratum removal, which will lead to partial or complete defaunation, expose underlying sediment which may be anoxic and/or of a different character and lead to changes in the topography of the area (Dernie *et al.*, 2003). Any remaining species, given their new position at the sediment water interface, may be exposed to unsuitable conditions.

Removal of 30 cm of sediment will remove species that occur at the surface and within the upper layers of sediment including *Crepidula fornicata*, the faunal community and the majority of the polychaetes.

Recovery of the sedimentary habitat would occur via infilling, although some recovery of the biological assemblage may take place before the original topography is restored, if the exposed, underlying sediments are similar to those that were removed. Newell *et al.* (1998) indicate that local hydrodynamics (currents and wave action) and sediment characteristics (mobility and supply) strongly influence the recovery of soft sediment habitats. It should be noted that the slipper limpets and ascidians are likely to rely on terrigenous debris in providing suitable for settlement.

Sensitivity assessment. Extraction of 30 cm of sediment will remove the characterizing biological component of the biotope. Resistance is assessed as '**None**' and biotope resilience is assessed as '**Medium**'. Sensitivity is, therefore, assessed as '**Medium**'.

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

Both the epifaunal and the infaunal species in the biotope are likely to be sensitive to physical disturbance due to dredging for scallops or oysters. Soft bodied epifauna, such as ascidians, are most vulnerable, and are likely to suffer high mortality. Sponges and hydroids attached to the slipper limpet bed are likely to be removed along the dredge track. Emergent epifauna are generally very intolerant of disturbance from fishing gear (Jennings & Kaiser, 1998).

Crepidula fornicata has a robust body form and so individuals are likely to be resistant of lighter abrasion events, although dredging has been used in clearance operations associated with protecting aquaculture (Sauriau *et al*., 1998; Cole & Hancock, 1956).The gregarious chain-forming characteristic of the species renders it susceptible to disturbance, as chains are more likely to be broken up, leaving some individuals exposed to predation.

It has been suggested that physical disturbance is a factor which could stimulate the presence of *Crepidula fornicata*, with reports suggesting it settles preferentially in the trails of trawl fishing gear (Sauriau *et al.* , 1998; De Montaudouin *et al*., 2001).

The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a passing dredge. The burrowing traits of the polychaetes may provide some tolerance of this pressure. However, Boldina and Beninger (2014) report decreases in naturally occurring aggregations of *Arenicola marina* in trawled areas suggesting consequences for basic biological characteristics such as reproduction, recruitment, growth and feeding. Ferns *et al*. (2000) reported a decline of 31% in populations of *Scoloplos armiger* (initial density 120 m^{-2}) in muddy sands and an 83% decline in *Pygospio elegans* (initial density 1850 m^{-2}) when a mechanical tractor towed harvester was used (in a cockle fishery). *Pygospio elegans* were significantly depleted for >100 days after harvesting (surpassing the study monitoring timeline). In a review of impacts of fishing activities on benthic communities, Collie *et al.* (2000) identified that well established sand and muddy sand intertidal communities suffered the greatest impact from bottom towed fishing activities. The review concluded that there were ecologically important impacts from removal of >50% of fauna from bottom towed fishing activity (dredge and trawls) (Collie *et al*., 2000).

Overall, a proportion of the slipper limpet bed, and its associated epifauna and infauna are likely to be removed or displaced.

Sensitivity assessment. Evidence suggests a decline in all species present following abrasion type events and resistance is, therefore, assessed as **'Low'**, resilience as **'High'** and sensitivity as **'Low'**.

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

Penetration and or disturbance of the substratum would result in similar, if not identical results as 'abrasion' for the epifaunal communities and *Crepidula fornicata*. The infaunal polychaetes may be more exposed to penetration type damage. The infaunal annelids are predominantly soft bodied, live within a few centimetres of the sediment surface and may expose feeding or respiration structures where they could easily be damaged by a physical disturbance such as a passing dredge The burrowing traits of the polychaetes may provide some tolerance of this pressure. However, Boldina and Beninger (2014) report decreases in naturally occurring aggregations of *Arenicola marina* in trawled areas suggesting consequences for basic biological characteristics such as reproduction, recruitment, growth and feeding. Ferns *et al*. (2000) reported a decline of 31% in populations of *Scoloplos armiger* (initial density 120 m^{-2}) in muddy sands and an 83% decline in *Pygospio elegans* (initial density 1850 m^{-2}) when a mechanical tractor towed harvester was used (in a cockle fishery). *Pygospio elegans* were significantly depleted for >100 days after harvesting (surpassing the study monitoring timeline). In a review of impacts of fishing activities on benthic communities , Collie *et al.* (2000) identified that well established sand and muddy sand intertidal communities suffered the greatest impact from bottom towed fishing activities. Mean response in muddy sand communities was much more negative than other habitats and most negative responses were for the polychaetes *Arenicola marina* and *Scoloplos armiger*. *Limecola balthica* and *Cerastoderma edule* were also more negatively impacted, although this may be due to direct targeting of *Cerastoderma edule* by cockle fisheries. The review concluded that there were ecologically important impacts from removal of >50% of fauna from bottom towed fishing activity (dredge and trawls) (Collie *et al*., 2000).

Sensitivity assessment. Resistance of the biotope is assessed as **'Low'**, although the significance of the impact for the bed will depend on the spatial scale of the pressure footprint. Resilience is assessed as **'Low'**, and sensitivity is assessed as '**High**'.

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

SS.SMx.SMxVS.CreMed occurs in lower estuarine waters and, therefore, the species in the biotope are likely to be well adapted to turbid conditions. Wass *et al.* (1999) described suspended sediment maxima for 'medium' sized rivers as rarely exceeding 500 mg/l, with a few rivers (including the Don and the Swale) experiencing concentrations in excess of 1000 mg/l. Langston *et al.* (2003) described annual mean suspended sediment concentrations in the Tamar as varying from 61 mg/l to 1039 mg/l in the upper estuary, 6 to 18 mg/l in the outer estuary and 2 to 9 mg/l beyond. It should be noted that the values quoted are mean annual concentrations and the same report states that conditions could be 'very turbid' in the outer estuary.

The estuarine turbidity maximum (the point at which highest turbidity is experienced) can be highly variable and has been reported to move by ca 12 km down-estuary during the transition from neap to spring tides in the Humber estuary (Uncles *et al*., 2001). Estuarine environments are likely to experience variable turbidity and the species present are probably tolerant of significant short-term changes in suspended solid concentrations.

Long-term increase in turbidity may affect primary production in the water column and therefore reduce the availability of diatom food, both for suspension feeders and deposit feeders. In addition, primary production by the microphytobenthos on the sediment surface may be reduced, further decreasing food availability for deposit feeders. Johnson (1972) noted that an increase in suspended solids above 100 mg/l resulted in lower growth rate and reduced filtration rate in *Crepidula fornicata.* However, the study found that the species survived in concentrations above 600 mg/l by continuously expelling pseudofaeces. The long-term effects of this strategy on survival were questioned.

Sensitivity assessment: The biotope occurs in outer estuaries and is therefore probably subject to variable turbidity. *Crepidula fornicata* is able to survive high turbidity events and is unlikely to be negatively affected by changes in turbidity at the benchmark level (the highest benchmark value is 300 mg/l). The infaunal polychaetes are likely to be resistant to changes in turbidity. Whilst an increase is therefore unlikely to have an impact on the biotope community, a significant, long-term decrease may lead to the development of a community of macroalgae which could potentially compete with some of the epifaunal species in the biotope, and result in loss of the biotope. Assuming a turbidity value of 'Intermediate' (10-100 mg/l), an increase to 'Medium' (100 -300 mg/l) is unlikely to have an effect. However a decrease to 'Clear' (<10 mg/l) could result in colonization from algal species. Whilst mortality from changes in suspended sediment are unlikely, colonization by algae could result in fundamental change in biotope. Given that the pressure benchmark is for one year, return to prevailing conditions would likely result in loss of the algae and full recovery to SS.SMx.SMxVS.CreMed or SS.SMx.SMxVS.CreAsAa. Resistance is, therefore, **'High'**, resilience is **'High'** and the biotope is **'Not sensitive'** at the benchmark level.

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

Stacks of adult *Crepidula fornicata* live attached to the substratum and are incapable of moving. They are active suspension feeders, generating a water current through the mantle cavity by ciliary action and trapping food particles on a mucous sheet lying across the front surface of the gill filament. Smothering with a 5 cm layer of sediment would be expected to clog the feeding and respiration structures. However, it has been demonstrated that *Crepidula fornicata* is capable of clearing its feeding structures at some energetic cost (Johnson, 1972). Furthermore, areas with large *Crepidula fornicata* populations do tend to become silted up through deposition of pseudofaeces, apparently with little effect on the species (Thouzeau *et al*., 2000) and, considering that *Crepidula fornicata* lives in chains of up to 12 individuals, at least some of the chain may avoid the effects of smothering. Therefore, although there may be some energetic cost as a result of smothering, probably resulting in decreased growth and reproductive output, there is unlikely to be mortality.

Polychaetes are infaunal, and deposition of fine material (e.g. continuous deposition) would be expected to lead to higher densities of macrobenthic organisms. For example, in the North Sea (Belgium) deposition of fine particle sediment, disturbed by scour around the base of a wind farm tower led to higher macrobenthic densities and created a shift in macrobenthic communities around the wind farm tower (influenced by the direction fine material had settled) (Coates *et al.*, 2014). Borja *et al.* (2000) classified the characterizing species *Mediomastus fragilis* as 'Group III' which 'tolerate disturbance and excess organic content'.

The faunal community considered in this report are generally permanently attached to the substratum and are active suspension feeders. Because adult *Styela clava* typically reach 8-12 cm (although it has been recorded up to 20 cm) (Neish, 2007), smothering with 5 cm of sediment is likely to only affect a small proportion of the population. Recovery should be rapid, facilitated by the remaining adults.

Sensitivity assessment. Removal of 5cm of sediment is likely to be occur and mortality among the characterizing species is unlikely. Therefore, resistance is assessed as '**High**', resilience as '**High**' and the biotope is **'Not sensitive'** at the benchmark level.

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

Stacks of adult *Crepidula fornicata* live attached to the substratum and are incapable of moving. They are active suspension feeders, generating a water current through the mantle cavity by ciliary action and trapping food particles on a mucous sheet lying across the front surface of the gill filament. Smothering with a 30 cm layer of sediment would bury the majority of the population, even after considering that *Crepidula fornicata* is capable of clearing its feeding structures at some energetic cost (Johnson, 1972).

It should be noted that areas with large *Crepidula fornicata* populations do tend to become silted up through deposition of pseudofaeces, apparently with little effect on the species (Thouzeau *et al*., 2000), a burial event at this level is likely to cause some mortality.

Polychaetes are infaunal, and deposition of fine material (e.g. continuous deposition) would be expected to lead to higher densities of macrobenthic organisms. For example, in the North Sea (Belgium) deposition of fine particle sediment, disturbed by scour around the base of a wind farm tower led to higher macrobenthic densities and created a shift in macrobenthic communities around the wind farm tower (influenced by the direction fine material had settled) (Coates *et al*., 2014). Within a Marine Biotic Index compiled by Borja *et al*. (2000), the characterizing species *Mediomastus fragilis* was classified as 'Group III' which tolerate disturbance and excess organic content.

The faunal community considered in this report are generally permanently attached to the substratum and are active suspension feeders. *Styela clava* typically reach 8-12 cm (although it has been recorded up to 20 cm) (Neish, 2007), smothering with 30 cm of sediment is likely bury the entire population

Sensitivity assessment: The evidence suggests that the characterizing *Crepidula fornicata* is quite resilient to sedimentation and burial, however, mortality could not be ruled out. Whilst the polychaetes are unlikely to be affected, the faunal community is likely to be entirely buried.. Where the biotope occurs in lower energy, removal of the sediment may be prolonged. Resistance is, therefore, assessed as '**Low**', resilience as '**High**' and sensitivity as '**Low**'.

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

'No evidence' was found.

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 found for effect of noise or vibrations on the characterizing species.

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

Whilst polychaetes have been reported to synchronize reproduction through light (Franke, 1986), introduction of light is unlikely to cause mortality among the characterizing species and resistance has been assessed as '**High**', resilience as '**High**' and the biotope is '**Not Sensitive**'.

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

'Not relevant'

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

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

Visual disturbance	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'.

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

Key characterizing species within this biotope are not cultivated or trans-located. This pressure is therefore considered '**Not relevant'** to this biotope group.

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

These biotopes are dominated by *Crepidula fornicata*, which is itself an Invasive Non-Indigenous Species. It has spread widely through Europe following introduction from North America at the end of the 19th century (Fretter & Graham, 1981; Eno *et al*., 1997). The invasive ascidian *Styela clava* is also present in SS.SMx.IMx.CreAsAn. This pressure is therefore '**Not relevant'**.

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

Gibbs (1971) reported that almost the entire population of *Aphelochaeta marioni* in Stonehouse Pool, Plymouth, UK was infected with a sporozoan parasite belonging to the acephaline gregarine genus *Gonospora*, which inhabits the coelom of the host. No evidence was found to suggest that gametogenesis was affected by *Gonospora* infection and there was no apparent reduction in fecundity. No information was found concerning infections of *Crepidula fornicata*.

Sensitivity assessment: No evidence of mortality in the characterizing species was found. Resistance is, therefore, assessed as '**High'**, resilience as '**High'** and the biotope is assessed as **'Not sensitive'**.

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

There is no evidence that any of the species in this biotope are exploited commercially. *Crepidula fornicata* is considered a pest on oyster beds (Fretter & Graham, 1981), and in response to the invasion of shellfisheries, some management has been attempted. Sauriau *et al*. (1998) and Cole & Hancock (1956) reported dredging operations to clear slipper limpets from oyster beds, but concluded that further spread of the species could not be prevented. Suction dredging has been used in France, with removal of 30,000 t/yr from St Brieuc Bay and the Bay of Mont Saint-Michel (Fitzgerald, 2007). The Bay of Mont Saint-Michel was reported to have a slipper limpet population of 100,000 tonnes in 1995-1996 which increased to 150,000 tonnes by 2005, despite the removal of 44,000 tonnes of slipper limpets during this period (Blanchard, 2009). The effect of dredging for slipper limpets would be similar to removing the upper layer of the substrata and therefore a decline in species richness is expected.

Sensitivity assessment. Whilst dedicated removal programmes by dredging for *Crepidula fornicata* exist, these have typically focused on limiting expansion and eradication (Fitzgerald, 2007; Sauriau *et al*. 1998). However, resistance is assessed as **'Low'**, resilience as **'High'** and sensitivity as **'Low'**.

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

Living infaunally, the polychaetes are unlikely to be affected directly from removal of *Crepidula fornicata*, however techniques for removing slipper limpets typically involve dredging or extraction, which would remove the top layer of the substrata and therefore be analogous to the penetration pressure assessed above. Therefore, if the *Crepidula fornicata* bed was removed by accident (e.g. as by-catch), then resistance is assessed as **'Low'**, resilience as **'High'** and sensitivity as **'Low'**.

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