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Pelvetia canaliculata and barnacles on moderately exposed littoral fringe rock

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

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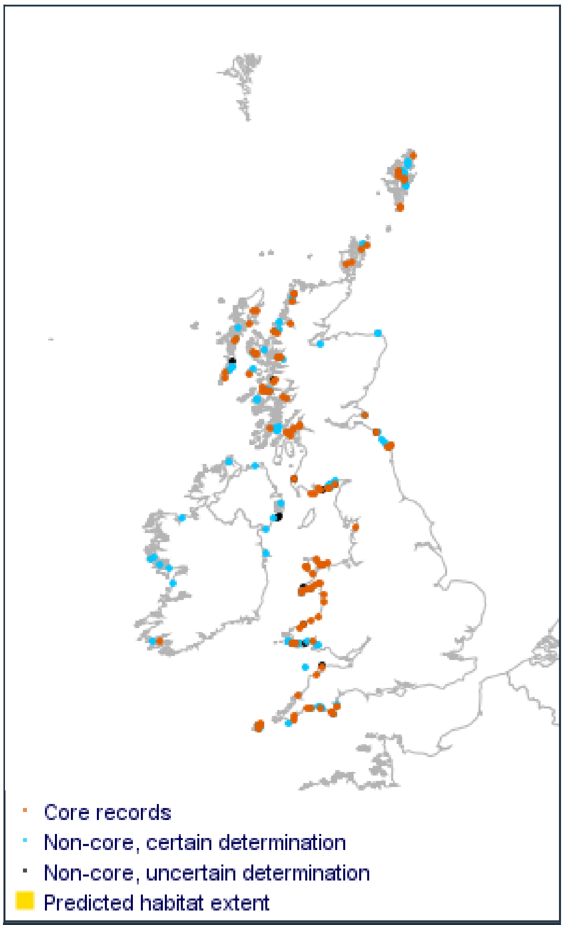
***Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock**
Photographer: Kate Northen
Copyright: Joint Nature Conservation Committee (JNCC)



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

Researched by Frances Perry **Refereed by** This information is not refereed.

Summary

UK and Ireland classification

EUNIS 2008	A1.211	*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
JNCC 2015	LR.MLR.BF.PelB	*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
JNCC 2004	LR.MLR.BF.PelB	*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock
1997 Biotope	LR.MLR.BF.PelB	*Pelvetia canaliculata* and barnacles on moderately exposed littoral fringe rock

Description

Exposed to moderately exposed, or sheltered steep, lower littoral fringe rock characterized by the upper shore fucoid wrack *Pelvetia canaliculata* and barnacles (moderately exposed southern and western shores are typically characterized by *Chthamalus* spp., with *Semibalanus balanoides* on northern and eastern shores). On sheltered shores the biotope is restricted to vertical faces. The limpet *Patella vulgata* and the wrack *Fucus spiralis* are usually present as well. *Pelvetia* sp. typically overgrows a crust of the black lichens Verrucaria maura and Verrucaria mucosa, in contrast to *Hildenbrandia rubra* on very sheltered shores (see Pel). The winkle *Littorina saxatilis* is frequently present underneath the fronds of *Pelvetia canaliculata*. Some geographical variation are present and southern and western shores are typically characterized by the barnacle *Chthamalus montagui* or *Chthamalus stellatus* while *Semibalanus balanoides* dominates on northern and eastern shores. On mixed substrata the barnacle *Elminius modestus* may be present. This biotope differs from the sheltered shore *Pelvetia* biotope (Pel) by the presence of some typically exposed-shore species; these include the grazing molluscs *Melarhaphe neritoides* and *Littorina neglecta* and the black lichen *Lichina pygmaea*. However, the striking difference exists in the greater number of barnacles by comparison to the sheltered shores. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

Strandline, Upper shore, Mid shore

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

Pelvetia canaliculata characterizes both LR.MLR.BF.PelB and LR.LLR.FVS.PelVS and the barnacles *Semibalanus balanoides* and *Chthalamus montagui* characterize LR.MLR.BF.PelB. *Pelvetia canaliculata* is a highly specialized extreme upper shore macroalgae found on intertidal rocky shores. In areas with moderate wave exposure this species can grow above the high water mark, in the splash zone. It also requires periods of emersion to survive; immersion for more than 6 hours in 12 can cause mortality (Schonbeck & Norton, 1979b). The barnacle species found within LR.MLR.BF.PelB varies depending on the geographic location. *Chthamalus montagui* dominates the barnacle population in this biotope in more southern and western locations, while *Semibalanus balanoides* dominates in northern and western locations. These biotopes have a relatively sparse fauna. *Fucus spiralis* can be found at the lower limits of these biotopes mixed in with *Pelvetia canaliculata*. However, *Fucus spiralis* is less tolerant of desiccation caused by either high temperatures or extended periods of emersion. The lichens *Verrucaria mucosa and Verrucaria maura* further contribute to the biological community within these biotopes. *Littorina saxatilis* is found within both LR.MLR.BF.PelB and LR.LLR.FVS.PelVS and *Patella vulgata* is also found within LR.MLR.BF.PelB. These species are the dominant grazers within these biotopes (Connor *et al.*, 2004). Although these other species are present, *Pelvetia canaliculata* is the dominant characterizing species, without which species the biotope would change. Therefore, the following sensitivity assessment focuses on the effect of pressures on this *Pelvetia canaliculata*.

Resilience and recovery rates of habitat

Recolonization experiments on *Pelvetia canaliculata* on the Isle of Man found growth rates varied between 1.8 – 4.8 cm /annum, with an average of 3.18 cm /annum (Subrahmanyan, 1960). Growth rates between 3 and 5 cm / annum were also recorded by Schonbeck & Norton (1980) and Rugg & Norton (1987). Growth rates in *Pelvetia canaliculata* were found to differ depending on shore height and level of shore exposure (Subrahmanyan, 1960). Those individuals found higher in the *Pelvetia* zone were smaller than those found lower down. The reason for dwarfism in *Pelvetia canaliculata* higher up in the shore zone is thought to be directly connected to the levels of desiccation (Subrahmanyan, 1960). Subrahmanyan (1960) found that *Pelvetia canaliculata* grew faster on more wave sheltered shores. *Pelvetia canaliculata* abundances also correlate with summer temperatures (Yesson *et al.*, 2015). Within *Pelvetia canaliculata* populations on the Isle of Man, the main growing period for *Pelvetia canaliculata* was from August through to December. This growth period was followed by a reproductive period which lasted from January, when receptacle maturation began, through to November. The peak release of gametes occurred in August and last until mid-September. The release of reproductive material coincided with spring tides to ensure that the gametes are released into a liquid medium. Individuals were found to reproduce at just a year old when fronds are only 4 – 5 cm in length, however, the number of receptacles was very low. In comparison to Subrahmanyan's (1960), findings *Pelvetia canaliculata* in Ireland reaches sexual maturity at a minimum age of two (perms. comm. D. Stengel). The time delay between gamete release and rhizoid production in *Pelvetia canaliculata* is roughly one week (Thuret & Bornet, 1878; Moss, 1974). Germlings prefer to settle on rough surfaces, there is also a higher survival rate on rough substrata (Subrahmanyan, 1960). Rugg & Norton (1987) noted the similarities between the eggs and zygotes of *Pelvetia canaliculata* and *Fucus* spp.. They go onto suggest that germlings of *Pelvetia canaliculata* could recruit some distance from the nearest mature stand as seen in some *Fucus* spp. who recruit in high numbers up to 60 m from the nearest sexually mature algae (Burrows & Lodge, 1950; taken from Rugg & Norton, 1987). *Pelvetia canaliculata* germlings have been found to settle below the *Pelvetia* zone on the shore, which shows their ability to disperse out of the parental zone (Schonbeck & Norton, 1980; Rugg & Norton, 1987). However, *Pelvetia canaliculata* is rapidly out-competed in these areas by faster growing lower shore species such as *Fucus spiralis* (Rugg & Norton, 1987). The average life expectancy of *Pelvetia canaliculata* on the Isle of man is estimated at four years (Subrahmanyan, 1960). The time taken from removal of *Pelvetia canaliculata* and its associated community to the establishment of a mature population was estimated to be four to five years (Subrahmanyan, 1960). This recovery time was estimated from removal experiments where patches either 0.5 m^2 or 1 m^2 were cleared within areas of mature *Pelvetia canaliculata*. In the Shetlands *Pelvetia canaliculata* only re-colonized shores, where the community had been bulldozed, 7-8 years after the disturbance event (Westwood *et al*., 1989). Subrahmanyan (1960) gives brief advice on how *Pelvetia canaliculata* should be harvested taking into consideration the ontogeny of the population on the Isle of Man. *Pelvetia canaliculata* below 14 cm should not be harvested due to the importance of those macroalgae in reproduction. Only individuals over 14 cm should be harvested as these are the plants in reproductive decline (Subrahmanyan, 1960).

Recovery of *Chthamalus montagui*, *Semibalanus balanoides* and the limpet *Patella vulgata* will depend on re-colonization by larvae. *Patella vulgata* is mobile, but the ability to relocate depends on the shore type and roughness (as described below). The characterizing animal species and others that are present, produce pelagic larvae. As these are common, widespread species, where the footprint of the impact is relatively small, larval supply from adjacent populations should support re-colonization. Where source populations are very distant due to regional impacts or habitat discontinuities, larval supply and recovery could be affected. Changes and recovery trajectories following the removal of key species are unpredictable and interactions between the key species may be positive or negative. Limpets may enhance barnacle settlement by removing algae from surfaces through grazing (Hawkins & Hartnoll, 1983) or by depositing pedal mucus trails that attract barnacle larvae (Holmes *et al*., 2005), or they may crush and displace newly settled individuals (Safriel *et al*., 1994). Barnacles may enhance survival of small limpets by moderating environmental stresses but they may also have negative effects on recruitment by occupying space and by limiting access to grazing areas. On the exposed to moderately exposed shores that this biotope occurs on, grazing may limit initial settlement of macroalgae but wave action will limit the presence of adults and larger species through, breakage and drag effects leading to loss. Mrowicki *et al*. (2014) found that limpet and barnacle removal allowed ephemeral and fucoid macroalgae to establish on sheltered and wave exposed shores in Ireland. Unlike the animal species macroalgae have short dispersal distances, over tens of metres (Dudgeon *et al*., 2001) and therefore recovery will require the presence of adults.

Re-colonization of *Patella vulgata* on rocky shores is rapid. Limpet spat appeared six months after the *Torrey Canyon* oil spill, with adults reaching peak numbers 4 - 5 years after the spill. However, although re-colonization was rapid, the alteration to the population structure (size and age class) persisted for about 15 years because of the complex cycles of dominance (see below) involving limpets, barnacles and algae (Hawkins & Southward, 1992, Lewis & Bowman, 1975). Hence the establishment of fucoids if *Patella vulgata* and other grazers were absent may lead to longer term exclusion of this species. In northern England, *Patella vulgata* reached sexual maturity in their second year (Blackmore, 1969) and thereafter reproduced annually. Limpets may change sex during their lifetime, with younger animals being male and older animals tending to be female (Blackmore, 1969). In Robin Hood's Bay, Lewis & Bowman (1975) observed spawning of *Patella vulgata* in the Autumn, with spatfall occurring in winter when desiccation pressures were lower. The rate and density of colonization is affected by the presence of other species. Lewis & Bowman

(1975), observed that mussels promote settlement of *Patella vulgata*. Settlement was also higher amongst barnacles and light coverings of algae. Dense coverings of mussels and fucoids, however, inhibit settlement through competition for space or prevention of settlement.

On rocky shores, barnacles are often quick to *colonize* available gaps. Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. Petraitis & Dudgeon (2005) also found that *Semibalanus balanoides* quickly recruited (present a year after and increasing in density) to experimentally cleared areas within the Gulf of Maine, that had previously been dominated by *Ascophyllum nodosum*. However, barnacle densities were fairly low (on average 7.6 % cover) because predation levels in smaller patches were high (Petraitis *et al*., 2003). Local environmental conditions, including surface roughness (Hills & Thomason, 1998), wind direction (Barnes, 1956), shore height, wave exposure (Bertness *et al*., 1991) and tidal currents (Leonard *et al*., 1998) have been identified, among other factors, as factors affecting settlement of *Semibalanus balanoides*. Biological factors such as larval supply, competition for space, presence of adult barnacles (Prendergast *et al*., 2009) and the presence of species that facilitate or inhibit settlement (Kendall *et al*., 1985, Jenkins *et al*., 1999) also play a role in recruitment. Mortality of juveniles can be high but highly variable, with up to 90 % of *Semibalanus balanoid*es dying within ten days (Kendall *et al*., 1985). Presumably these factors would also influence the transport, supply and settlement of *Chthamalus montagui*.

The lifespan of *Chthamalus montagui* is relatively short at 2-3 years (Southward & Crisp, 1950). Sexual maturity can be reached in the first year and a number of broods may be produced each year. Shore height affects a number of life history parameters, growth is more rapid and the mortality rate is greater lower down on the shore (Southward & Crisp, 1950). Towards the northern limits of distribution annual recruitment is low (Kendall & Bedford, 1987) and they have an increased longevity (Lewis, 1964). Burrows *et al*. (2000) found that the fecundity of *Chthamalus montagui* generally increased lower down the shore, with estimations of 1-2 broods per year at high shore levels, 2 to over three at mid shore levels, and over 2 to over 4 at low shore levels. Throughout the breeding season most individuals produce several broods (Burrows *et al*., 1992; O'Riordan *et al*., 1992), with a small percentage of the population remaining reproductively active throughout the year (O'Riordan *et al*., 1995; Barnes, 1989).

Little evidence was found for the recovery of the lichens *Verrucaria maura* and *Verrucaria mucosa*. However information on the recovery of lichens as a group suggest that for mature lichens to return to a shore could take in excess of 10 years. Sexual spores and asexual propagules of lichens are probably widely dispersed by the wind and mobile invertebrates. Lichen growth rates are low, rarely more than 0.5-1mm/year in crustose species while foliose species may grow up to 2-5mm/year. Cullinane *et al*. (1975) noted that many of the lichens lost due to an oil spill in Bantry Bay were probably 20-50 years old based on their size, and lifespans of lichens have been estimated to be 100 years or more (Jones *et al*., 1974). Fletcher (1980) suggested that newly exposed substratum needs to be modified by weathering and that initiation of new thallus is thought to take several years. Crump & Moore (1997) observed that lichens had not colonized experimentally cleared substrata within 12 months. Brown (1974) reported that re-colonization of substrata within Caerthillian Cove, Cornwall, which was heavily affected by oil and dispersants after the *Torrey Canyon* oil spill, took 7 years to begin. Recovery of lichens communities from damage will probably take many years. In heavily damaged areas, the prolonged re-colonization period and subsequent slow growth is likely to take a very long time and recovery rates are likely to be extremely slow, probably in excess of ten years (Holt *et al*., 1995).

The other biological components are not pivotal to the presence of this biotope. *Littorina saxatilis* are mobile and will be able to relocate if they are intolerant of a pressure. They will then be able to migrate back up the shore to re-colonize once the pressure has been removed. Depending on the pressure and its severity *Fucus spiralis* resilience varies. After the *Torrey Canyon* oil spill, oil dispersants were used to emulsify the oil on intertidal rocky shores in the south-west of England. These dispersants removed large percentages of fauna and flora from intertidal rocky shores (Hawkins & Southward, 1992). It took between 10 and 15 years for the *Fucus* spp. (including *Fucus spiralis*) to return to 'normal' levels of spatial and variation in cover on moderately exposed shores. However, dense stands of fucoids had returned to rocky shores within five years of the *Torrey Canyon* spill (Hawkins & Southward, 1992). The long period of time between return of fucoids and ecosystem balance was due to the imbalance between grazers, microalgae's and other fauna. For factors which are likely to totally destroy the biotope, recoverability will be low. If species from the biotope and some *Fucus spiralis* remains after a disturbance event it is likely that recovery of ecosystem function will occur within 2 – 10 years.

Resilience assessment: *Pelvetia canaliculata* has high physiological and biochemical resilience to environmental conditions on the high shore. Compared to fucoids such as *Ascophyllum nodosum*, *Pelvetia canaliculata* has a relatively short life expectancy of four years. The population turns over quickly with individuals becoming sexually mature at 1-2 years. The ability of *Pelvetia canaliculata* to repopulate a shore depends on the scale of removal. Subrahmanyan (1960) estimated that recovery to a mature stand of *Pelvetia canaliculata* after complete removal would take five years. However, reports from larger scale removal on the Shetlands found that *Pelvetia canaliculata* only re-colonized the intertidal shore 7 – 8 years after the disturbance event (Westwood *et al*., 1989). Evidence suggests that the size of the footprint of an impact and the magnitude will influence the recovery rates by mediating settlement and post-settlement recruitment of both barnacles and limpets. Barnacles are attracted to settle in the presence of adults of the same species (Prendergast *et al*., 2009); so the presence of adults will facilitate recovery. *Fucus spiralis* can re-colonize a shore within five years, but for ecosystem function to return after a pressure has removed the majority of the biotope can take up to 15 years (Hawkins & Southward, 1992). *Verrucaria* spp. can show some recovery within ten years of the pressure event, but for a mature stand of lichen to return may take in excess of ten years. If there is partial removal of the characterizing species from these biotopes the resilience is considered to be 'Medium' due to the recovery speed of the characterizing species and the other species in the biotope. However, if there is removal of the entire community from a shore and there are no mature populations nearby from which species can recruit, resilience would be 'Low'.

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 recognisable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity

Temperature increase (local)	Medium Q: High A: High C: High	Medium Q: Medium A: High C: Medium	Medium Q: Medium A: High C: Medium

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Little evidence was found for the recovery of the lichens *Verrucaria maura* and *Verrucaria mucosa*. However information on the recovery of lichens as a group suggest that for mature lichens to return to a shore could take in excess of 10 years. Sexual spores and asexual propagules of lichens are probably widely dispersed by the wind and mobile invertebrates. Lichen growth rates are low, rarely more than 0.5-1mm/year in crustose species while foliose species may grow up to 2-5mm/year. Cullinane *et al.* (1975) noted that many of the lichens lost due to an oil spill in Bantry Bay were probably 20-50 years old based on their size, and lifespans of lichens have been estimated to be 100 years or more (Jones *et al*., 1974). Fletcher (1980) suggested that newly exposed substratum needs to be modified by weathering and that initiation of new thallus is thought to take several years. Crump & Moore (1997) observed that lichens had not colonized experimentally cleared substrata within 12 months. Brown (1974) reported that re-colonization of substrata within Caerthillian Cove, Cornwall, which was heavily affected by oil and dispersants after the *Torrey Canyon* oil spill, took 7 years to begin. Recovery of lichens communities from damage will probably take many years. In heavily damaged areas, the prolonged re-colonization period and subsequent slow growth is likely to take a very long time and recovery rates are likely to be extremely slow, probably in excess of ten years (Holt *et al*., 1995).

The other biological components are not pivotal to the presence of this biotope. *Littorina saxatilis* are mobile and will be able to relocate if they are intolerant of a pressure. They will then be able to migrate back up the shore to re-colonize once the pressure has been removed. Depending on the pressure and its severity *Fucus spiralis* resilience varies. After the *Torrey Canyon* oil spill, oil dispersants were used to emulsify the oil on intertidal rocky shores in the south-west of England. These dispersants removed large percentages of fauna and flora from intertidal rocky shores (Hawkins & Southward, 1992). It took between 10 and 15 years for the *Fucus* spp. (including *Fucus spiralis*) to return to 'normal' levels of spatial and variation in cover on moderately exposed shores. However, dense stands of fucoids had returned to rocky shores within five years of the *Torrey Canyon* spill (Hawkins & Southward, 1992). The long period of time between return of fucoids and ecosystem balance was due to the imbalance between grazers, microalgae’s and other fauna. For factors which are likely to totally destroy the biotope, recoverability will be low. If species from the biotope and some *Fucus spiralis* remains after a disturbance event it is likely that recovery of ecosystem function will occur within 2 – 10 years.

Resilience assessment: *Pelvetia canaliculata* has high physiological and biochemical resilience to environmental conditions on the high shore. Compared to fucoids such as *Ascophyllum nodosum*, *Pelvetia canaliculata* has a relatively short life expectancy of four years. The population turns over quickly with individuals becoming sexually mature at 1-2 years. The ability of *Pelvetia canaliculata* to repopulate a shore depends on the scale of removal. Subrahmanyan (1960) estimated that recovery to a mature stand of *Pelvetia canaliculata* after complete removal would take five years. However, reports from larger scale removal on the Shetlands found that *Pelvetia canaliculata* only re-colonized the intertidal shore 7 – 8 years after the disturbance event (Westwood *et al*., 1989).

Evidence suggests that the size of the footprint of an impact and the magnitude will influence the recovery rates by mediating settlement and post-settlement recruitment of both barnacles and limpets. Barnacles are attracted to settle in the presence of adults of the same species (Prendergast *et al*., 2009); so the presence of adults will facilitate recovery. *Fucus spiralis* can re-colonize a shore within five years, but for ecosystem function to return after a pressure has removed the majority of the biotope can take up to 15 years (Hawkins & Southward, 1992). *Verrucaria* spp. can show some recovery within ten years of the pressure event, but for a mature stand of lichen to return may take in excess of ten years. If there is partial removal of the characterizing species from these biotopes the resilience is considered to be 'Medium' due to the recovery speed of the characterizing species and the other species in the biotope. However, if there is removal of the entire community from a shore and there are no mature populations nearby from which species can recruit, resilience would be 'Low'.

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 recognisable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

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

Pelvetia canaliculata is common throughout the British Isles. The distribution of *Pelvetia canaliculata* extends as far north as Iceland and Norway. Although species ranges may not accurately describe their ability to withstand localized changes in temperature. They may to some extent display the limits of the species genetic ability to acclimatize to temperatures. The growth rates and photosynthetic capabilities of macroalgae vary due to seasonal acclimation (Davison *et al*., 1989). A 5 °C decrease in temperature is likely to lower growth rates in *Pelvetia canaliculata,* unless the decrease occurs during a summer when temperatures are in excess of 25 °C (Pfetzing *et al*., 2000). Acclimation to a decrease in temperature is likely in *Pelvetia canaliculata* considering its range. However, if a rapid 5 °C decrease were to occur in the winter the species may not be able to acclimate in time and some permanent damage may occur. During warmer summer months a decrease in temperature can lead to lowered levels of evaporation and consequently lower levels of desiccation. This could be beneficial if temperatures are in excess of 25 °C (Pfetzing *et al*., 2000).

Fucus spiralis is at the top of its temperature tolerance in this biotope. Any decrease in temperature could allow this species to extend further up the shore. *Fucus spiralis* can out-compete *Pelvetia canaliculata* as it grows faster and overshadows the slower growing *Pelvetia canaliculata*. A decrease in temperature may reduce habitat suitability for *Chthalamus montagui*, the more warm adapted species. Changes in temperature may lead to *Semibalanus balanoides* replacing *Chthalamus montagui*. As the environmental niche is still being filled by a barnacle species this will not make any important changes in the biotopes to which barnacles are relevant.

Sensitivity assessment. Direct empirical evidence on the cold tolerance of *Pelvetia canaliculata* is unavailable. Instead and assessment has been made using the available information on the acclimation and upper temperature tolerance of *Pelvetia canaliculata.* This evidence suggests that this species is unlikely to be significantly negatively affected by a change in temperature at the pressure benchmark. The only case during which some mortality may occur is if a decrease of 5 °C for a month occurred during winter, when *Pelvetia canaliculata* may not be able to acclimate fast enough. *Fucus spiralis* may move further higher on the shore, possibly causing a change in the biotope lower limit. Within LR.MLR.BF.PelB the dominant barnacle species may change, but the function niche will still be filled. The resistance and resilience have been assessed as ‘High’, resulting in a ‘Not sensitive’ assessment.

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

Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal therefore have behavioural or physiological adaptations to changes in salinity.

Fucus spiralis is tolerant of short-term increases in salinity. *Fucus spiralis* populations in New Hampshire were reported to survive between 2 – 32psu (Niemeck & Mathieson, 1976). *Littorina saxatilis* is a mobile species has the ability to remove itself from unfavourable conditions. This littorinid is also found occasionally in upper shore rock pool biotopes (such as LR.FLR.Rkp.G). Its presence in biotopes where salinities are highly variable is evidence for this species ability to cope with short-term fluctuations in salinity. However, the impact of more long-term increases in salinity is unknown.

Semibalanus balanoides is tolerant of a wide range of salinities, and has the ability to isolate itself from water by closing their opercula valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 psu (Jenkins *et al.*, 2001b). Barnes & Barnes (1974) found that larvae from both *Chthamalus stellatus* and *Semibalanus (as Balanus) balanoides*, completed their development to nauplii larvae at salinities between 20-40%.

Sensitivity assessment. *Pelvetia canaliculata* biotopes exist in both full (30 – 40) and variable (18 – 40) salinities (Connor *et al.*, 2004). LR.MLR.BF.PelB occurs only in fully marine conditions if there was to be an increase in the salinity regime within this biotope the conditions would become hypersaline. There is no epirical evidence to suggest how the species within this biotope would react to these condtions. LR.LLR.FVS.PelVS occurs only in variable salinity regimes. Here a change in salinity would create a full salinity regime. The conditions for many of the constiuent species would become more optimal and as such there would not be a decrease in the health of this biotope. It is not clear how LR.MLR.BF.PelB would change in hypersaline conditions but as conditions for this biotope are no longer optimal there is likely to be a decrease in the characterizing species resulting in the resilience and resistance being 'Medium'. And an overall sensitivity assessment of 'Medium'. LR.LLR.FVS.PelVS is assessed to have a 'High' resistance and resilience to this pressure. Giving an overall sensitivity of 'Not sensitive'.

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

Biotopes found in the intertidal will naturally experience fluctuations in salinity where evaporation increases salinity and inputs of rainwater expose individuals to freshwater. Species found in the intertidal, therefore, have behavioural or physiological adaptations to changes in salinity. *Fucus spiralis* is tolerant of decreases in salinity.

Fucus spiralis populations in New Hampshire were reported to survive between 2 – 32 psu (Niemeck & Mathieson, 1976). *Littorina saxatilis* is a mobile species has the ability to remove itself from unfavourable conditions. This littorinid is also found occasionally in upper shore rock pool biotopes (such as LR.FLR.Rkp.G). Its presence in biotopes where salinities are highly variable is evidence for this species ability to cope with short-term fluctuations in salinity. A long-term decrease in salinity is unlikely to have an effect on *Fucus spiralis* in this biotope.

Semibalanus balanoides is tolerant of a wide range of salinities, and has the ability to isolate itself from water by closing their opercula valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 (Jenkins *et al.*, 2001b). Barnes & Barnes (1974) found that larvae from both *Chthamalus stellatus* and *Semibalanus (as Balanus) balanoides*, completed their development to nauplii larvae at salinities between 20-40%.

Sensitivity assessment. *Pelvetia canaliculata* biotopes exist in both full (30 – 40) and variable (18 – 40) salinities (Connor *et al.*, 2004). LR.MLR.BF.PelB occurs only in fully marine conditions if there a decrease in the salinity regime within this biotope the conditions would become reduced. There are functioning *Pelvetia canaliculata* biotopes within this salinity regime, which shows the characterizing species ability to survive, long-term, within this salinity regime. LR.LLR.FVS.PelVS occurs only in variable salinity regimes. Here a change in salinity would create a reduced salinity regime. The conditions for many of the constituent species would no longer be optimal, as many of the species can only survive short periods of time at reduced salinity levels. Consequently there would be a decrease in the health of this biotope. For LR.LLR.FVS.PelVS the resilience and resistance being 'Medium'. And an overall sensitivity assessment of 'Medium'. LR.MLR.BF.PelB is assessed to have a 'Medium' resistance and resilience to this pressure. As although there wouldn't be mortality of the characterizing species, the shift in salinity regime would cause a change to an alternative biotope. Giving an overall sensitivity of 'Medium'.

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

LR.LLR.FVS.PelVS can be found in very weak (negligable) to moderately strong (1 - 3 knots) tidal streams. LR.LLR.FVS.PelB can be found in very weak to strong (3 – 6 knots) tidal streams (Connor *et al.*, 2004). Although no empirical data can be found on the effects of water flow on *Pelvetia canaliculata*, a study into its effects on *Fucus spiralis* found that plants were torn from their anchorage at 7 – 8 m/sec (Jonsson *et al.*, 2006). If water flows were to increase above 3 m/sec, plants may not be immediately torn from the substrate but dispersal, fertilization, settlement and recruitment may be affected (Pearson & Brawley, 1996). Risk of dislodgement will also increase where algae are attached to smaller sediment fractions instead of bedrock. If sediment type is small and the substratum is less stable, individuals may reach a critical size when the drag force exceeds gravity and the plant is moved together with its substratum (Malm, 1999). A decrease in water flow is unlikely to have a negative impact on this biotope as it occurs most frequently at very weak water flows (< 0.5 m/sec.) (Connor *et al.*, 2004).

Growth and reproduction of *Semibalanus balanoides* is influenced by food supply and water velocity (Bertness *et al*., 1991). Laboratory experiments demonstrate that barnacle feeding behaviour alters over different flow rates but that barnacles can feed at a variety of flow speeds (Sanford *et al*., 1994). Flow tank experiments using velocities of 0.03, 0.07 and 0.2 m/s showed that a higher proportion of barnacles fed at higher flow rates (Sanford *et al*., 1994). Feeding was passive, meaning the cirri were held out to the flow to catch particles; although active beating of the cirri to generate feeding currents occurs in still water (Crisp & Southward, 1961). Field observations at sites in southern New England (USA) found that *Semibalanus balanoides* from all sites responded quickly to higher flow speeds, with a higher proportion of individuals feeding when current speeds were higher. Barnacles were present at a range of sites, varying from sheltered sites with lower flow rates (maximum observed flow rates <0.06- 0.1 m/s), a bay site with higher flow rates (maximum observed flows 0.2-0.3 m/s) and open coast sites (maximum observed flows 0.2-0.4 m/s). Recruitment was higher at the site with flow rates of 0.2-0.3 m/s (although this may be influenced by supply) and at higher flow microhabitats within all sites. Both laboratory and field observations indicate that flow is an important factor with effects on feeding, growth and recruitment in *Semibalanus balanoides* (Sanford *et al*., 1994; Leonard *et al*., 1998), however, the results suggest that flow is not a limiting factor determining the overall distribution of barnacles, including *Chthamalus montagui* as they can adapt to a variety of flow speeds.

Patella vulgata inhabits a range of tidal conditions and is therefore, likely to tolerate a change in water flow rate. The streamlined profile of limpet shells is of importance in increasing their tolerance of water movement, and this is undoubtedly one factor in determining the different shape of limpets at different exposures. With increasing exposure to wave action the shell develops into a low profile reducing the risk of being swept away. The strong muscular foot and a thin film of mucus between the foot and the rock enable *Patella vulgata* to grip very strongly to the substratum (Fretter & Graham, 1994). The ability of limpets to resist accelerating, as distinct from constant currents, may set a limit to the kind of habitat which they can occupy and limit the size to which they can grow.

Sensitivity assessment: At the level of the benchmark a change in water flow will not have an impact on the biological communities within these biotopes. Consequently both resistance and resilience have been assessed as 'High', resulting in an overall sensitivity of 'Not Sensitive'.

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

Of the fucoids found in the British Isles, *Pelvetia canaliculata* is the better adapted to desiccation stresses, therefore, it is often the dominant macroalgae high on intertidal rocky shores. *Pelvetia canaliculata* can spend as much as 90% of its time out of water (Fish & Fish, 1996) and has been found to survive up to 8 days emersion (Pfetzing, 2000) and as much as 65% water loss (Schonbeck & Norton, 1978). Schonbeck & Norton (1980) found that *Pelvetia canaliculata* can recover well from desiccation, and can also increase desiccation tolerance quickly (Schonbeck & Norton, 1979). Recovery from desiccation includes the ability to quickly regain nutrient uptake and photosynthesising capability (Hurd & Dring, 1990, 1991). Field observations of *Pelvetia canaliculata* on the Isle of Cumbrae by Schonbeck & Norton (1978) found that environmental conditions constantly pruned the higher limits of this species. Individuals in the upper part of the *Pelvetia* zone were found to suffer tissue damage 21 – 28 days after neap tides coincided with drying conditions and especially high air temperatures (Schonbeck & Norton, 1978). Subrahmanyan (1960) observed that on the Isle of Man when neap tides and calm condition coincided, the water did not reach the bottom of the *Pelvetia canaliculata* habitat. However, spring high tides cover the entire habitat. The release of *Pelvetia canaliculata* reproductive bodies are reported to occur on a two weekly cycle, during spring high tides (Subrahmanyan, 1960). This ensures that gametes are released into a liquid medium. The lower limits of *Pelvetia* are controlled by interspecific competition. Lower on the shore *Fucus spiralis* is able to grow faster than *Pelvetia canaliculata*, and out-competes *Pelvetia canaliculata* for resources (Subrahmanyan, 1960). *Pelvetia canaliculata* is also heavily grazed lower on the shore (Subrahmanyan, 1960). In addition to interspecific competition, submersion induced decay limits *Pelvetia canaliculata's* ability to survive lower on the shore (Rugg & Norton, 1987). If *Pelvetia canaliculata* is submerged for six or more hours in every 12, rot begins (Rugg & Norton, 1987; Schonbeck & Norton, 1979). Visible signs of rot begin roughly four weeks after high levels of immersion begin (Rugg & Norton, 1987). This rot is fatal to *Pelvetia canaliculata* if immersion is not decreased. The occurrence of the rot is definite and has been tested in a range of different environmental conditions; the reason for the occurrence isn't known and could be infections, or caused by *Pelvetia canaliculata's* inability to live underwater (Rugg & Norton, 1987).

Increased emergence would reduce the feeding time and increase desiccation for barnacles within the biotope. *Chthamalus montagui* are very tolerant of high periods of emersion, yet Patel & Crisp (1960) found that when barnacles which were brooding eggs were kept out of the water, a second batch of eggs was not produced. Decreased emergence is likely to lead to the habitat the biotope is found in becoming more suitable for the lower shore species generally found below the biotope, leading to replacement. Competition between *Semibalanus balanoides* and *Chthalamus montagui* is likely to play an important role in the changes in species distribution. *Semibalanus balanoides* is less tolerant of desiccation stress than *Chthamalus montagui* but is considered to out-compete *Chthamalus montagui* in the mid and lower shore. Mobile species found within these biotopes such as littorinids and *Patella vulgata* are able to relocate if physiological pressures become too strong.

Sensitivity assessment. Although *Pelvetia canaliculata* is highly adapted to long periods of emersion, the upper limit of this species is limited by environmental conditions linked to high air temperatures. Those *Pelvetia canaliculata* individuals living at the highest level on the shore are living at the top of their physiological tolerance limits and so would not be likely to tolerate an increase in emersion levels. Consequently the upper limit of this biotope would be depressed if there was a decrease in immersion. Decreases in the level of emersion would result in the species being competitively displaced by faster growing species such as *Fucus spiralis* the fucoid which usually grows below *Pelvetia canaliculata*. If there was a lack of *Fucus spiralis* below the *Pelvetia* zone then *Pelvetia canaliculata* would succumb to the rot, bought on by greater levels of immersion. Similar changes in distributions of other species associated with the relevant biotopes will occur. The resistance of this biotope to this pressure is 'Low', resilience is 'Medium' giving a sensitivity of 'Medium'.

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

An increase in wave exposure generally leads to a decrease in macroalgae abundance and size (Lewis, 1961, Stephenson & Stephenson, 1972, Hawkins *et al.*, 1992, Jonsson *et al.*, 2006). On the Isle of Man, the density of *Pelvetia canaliculata* was found to be inversely proportional to the level of wave exposure (Subrahmanyan, 1960). The greater the wave exposure, the less dense the growths of *Pelvetia canaliculata*. In moderately exposed conditions, *Pelvetia canaliculata* is capable of growing above the high water mark, where is it supplied with water through spray and wave splash. In more sheltered conditions, *Pelvetia canaliculata* is found further down the shore where it is immersed by spring tides.

*Chthamalus montagu*i increases in abundance in sheltered locations and towards the high-water neap-tide level on all shores where chthamalid species occur. The edible periwinkle *Littorina littorea* may also colonize suitable areas following a decrease in wave exposure. A decrease in wave exposure may ultimately reduce *Patella vulgata* abundance because the species does not favour thick algal cover that is often present on very sheltered shores. Alternatively an increase in significant wave height, linked to increased exposure, may result in population changes with fewer barnacles present and with the limpet *Patella ulyssiponensis* present, or present in greater numbers, rather than P*atella vulgata* (Thompson, 1980).

Sensitivity assessment. At the pressure benchmark this biotope will not be affected. Therefore, resistance and resilience are both 'High', resulting in a sensitivity assessment of 'Not sensitive'.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

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

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

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

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

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

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

No evidence.

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

This pressure is **Not assessed**.

De-oxygenation	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Cole *et al*. (1999) suggested possible adverse effects on marine species below oxygen levels of 4 mg/l and probable adverse effects below 2 mg/l. Sustained reduction of dissolved oxygen can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. Continued or repeated episodes of reduced dissolved oxygen have the potential to severely degrade an ecosystem (Cole *et al*., 1999). Reduced oxygen concentrations have been shown to inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al*., 2012). If levels do drop below 4 mg/l negative effects on marine organisms can be expected with adverse effects occurring below 2mg/l (Cole *et al*., 1999). Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly. However, small invertebrate epifauna may be lost, causing a reduction in species richness.

In laboratory experiments a reduction in the oxygen tension of seawater from 148 mmHg (air saturated seawater) to 50 mm Hg rapidly resulted in reduced heart rate in limpets of the genus *Patella* (Marshall & McQuaid, 1993). Heartbeat rate returned to normal in oxygenated water within two hours. Limpets can survive for a short time in anoxic seawater; Grenon & Walker, (1981) found that in oxygen-free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. Therefore, some individuals may survive for one week at an oxygen concentration of 2 mg/l. Exposure would be mediated by the position of the biotope in the upper to mid-shore as *Patella vulgata* is able to respire in the air and would only be exposed to low oxygen in the water column intermittently during periods of tidal immersion. In addition, in areas of wave exposure and moderately strong current flow low oxygen levels in the water are unlikely to persist for very long.

Barnacles, in general, seem to have a high tolerance of anaerobic conditions. *Chthamalus montagui* has been shown to be relatively unaffected by smothering by oil. Monterosso (1930) showed experimentally that the species can survive complete smothering by petroleum jelly for approximately two months. Complete smothering caused by the *Torrey Canyon* oil spill yielded similar results; a few *Semibalanus balanoides* died, yet *Chthamalus montagui* seemed unaffected (Smith, 1968). *Semibalanus balanoides* can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al*., 1963).

Sensitivity assessment. The characterizing species *Pelvetia canaliculata* and the associated community require oxygen. However, this macroalga spends extended periods of time emersed due to its location on the upper shore. LR.MLR.BF.PelB occurs in the littoral fringe, which is rarely inundated and is often exposed to the air, and consequently, a large proportion of time will be spent in the air where oxygen is not limited so the metabolic processes of photosynthesis and respiration can take place. The high shore location of barnacles within the LR.MLR.BF.PelB biotope may be negatively affected by reduced levels of oxygen due to the short time frame in which they are immersed. Although the evidence does suggest that barnacles are tolerant of reduced oxygen levels. Even if the water lapping over the littoral fringe was deoxygenated, wave action (in this wave exposed biotope) and turbulent flow over the rock surface would probably aerate the water column. Hence, the biotope is unlikely to be exposed to deoxygenated conditions and the pressure is considered to be 'Not relevant'.

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

The nutrient enrichment of a marine environment leads to organisms no longer being limited by the availability of certain nutrients. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as a contaminants, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Not all of the 47 papers considered the impact of nutrients on intertidal rocky shores. Yet this finding is still relevant as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However research into the impacts of nutrient enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

Nutrient enrichment alters the selective environment by favouring fast growing, ephemeral species such as *Ulva lactuca* and *Ulva intestinalis* (Berger *et al.*, 2004, Kraufvelin, 2007). Rohde *et al.* (2008) found that both free growing filamentous algae and epiphytic microalgae can increase in abundance with nutrient enrichment. This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Berger et al., 2003; Kraufvelin *et al.*, 2007). Nutrient enrichment can also enhance fouling of *Fucus* fronds by biofilms (Olsenz, 2011). Nutrient enriched environments can not only increase algae abundance, but the abundance of grazing species (Kraufvelin, 2007).

Changes in community composition on intertidal rocky shores can happen rapidly, and fast growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast growing ephemeral species can become well established quickly, healthy communities on intertidal rocky shores can survive long periods of time, and maintain ecological function after these species have become established (Bokn *et al.*, 2002, 2003, Karez *et al.*,2004, Kraufvelin, 2007, Kraufvelin *et al.*, 2006).

Sensitivity assessment. A slight increase in nutrients may enhance growth rates but high nutrient concentrations could lead to the overgrowth of the algae by ephemeral green algae and an increase in the number of grazers. However, if the biotope is well established and in a healthy state the biotope could have the potential to persist. The effect of an increase in this pressure to the benchmark level should not have a negative impact on the biotope. Therefore the resistance has been assessed as 'High'. As there will be nothing for the biotope to recover from therefore the resilience is also 'High'. These two rankings give an overall sensitivity of 'Not Sensitive'.

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

The organic enrichment of a marine environment at this pressure benchmark leads to organisms no longer being limited by the availability of organic carbon. The consequent changes in ecosystem functions can lead to the progression of eutrophic symptoms (Bricker *et al.*, 2008), changes in species diversity and evenness (Johnston & Roberts, 2009) and decreases in dissolved oxygen and uncharacteristic microalgae blooms (Bricker *et al.*, 1999, 2008).

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 49 papers reviewed relating to sewage as a contaminant, over 70% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. Not all of the 49 papers considered the impact of sewage on intertidal rocky shores. Yet this finding is still relevant as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

Organic enrichment alters the selective environment by favouring fast growing, ephemeral species such as *Ulva lactuca* and *Ulva intestinalis* (Berger *et al.*, 2004, Kraufvelin, 2007). Rohde *et al.* (2008) found that both free growing filamentous algae and epiphytic microalgae can increase in abundance with nutrient enrichment. This stimulation of annual ephemerals may accentuate the competition for light and space and hinder perennial species development or harm their recruitment (Berger et al., 2003; Kraufvelin *et al.*, 2007). Nutrient enrichment can also enhance fouling of fucoid fronds by biofilms (Olsenz, 2011). Nutrient enriched environments can not only increase algae abundance, but the abundance of grazing species (Kraufvelin, 2007). Bellgrove *et al.* (2010) found that coralline turfs out-competed fucoids at a site associated with organic enrichment caused by an ocean sewage outfall.

Changes in community composition on intertidal rocky shores can happen rapidly, and fast growing ephemeral species can become established quickly in the presence of higher concentrations of nutrients. The establishment and growth of these species are not controlled by wave exposure (Kraufvelin, 2007). However, even though these fast growing ephemeral species can become well established quickly, healthy communities on intertidal rocky shores can survive long periods of time, and maintain ecological function after these species have become established (Bokn *et al.*, 2002, 2003, Karez *et al.*,2004, Kraufvelin, 2007, Kraufvelin *et al.*, 2006b).

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. Due to the potential negative impacts that have been reported to result from the introduction of excess organic carbon, resistance has been assessed as 'Medium' and resilience has been assessed as 'Medium'. This gives an overall sensitivity score of 'Medium'.

Physical Pressures

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

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

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

This biotope occurs on hard rock bedrock, boulders and cobbles, a change in substratum would significantly alter the character of the biotope and would lead to the development of a biological assemblage more typical of the changed conditions. A change to an artificial substratum could also impact this biotope as species may have settlement preferences for particular surface textures. Therefore the replacement of natural surfaces with artificial ones may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2013).

Sensitivity assessment. A change in substratum would result in the loss of the characterizing species *Pelvetia canaliculata* along with other species associated with this biotope. Resistance is assessed as 'None'. As this pressure represents a permanent change, recovery is impossible as the suitable substratum for the biological community of this biotope is lacking. Consequently, resilience is assessed as 'Very Low'. The habitat, therefore, scores a 'High' sensitivity. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	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 occurring 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

The species characterizing this biotope occur on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

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

Trampling on the rocky shore has been observed to reduce fucoid cover, decrease the microhabitat available for epiphytic species, increase bare space and increase cover of opportunistic species such as *Ulva* (Fletcher & Frid, 1996a). This biotope is found in the upper intertidal shore. An area easily accessible by humans especially at low tide. Individual microalgae's are flexible but not physically robust. Fucoids are intolerant of abrasion from human trampling, which has been shown to reduce the cover of seaweeds on a shore (Holt *et al.*, 1997; Tyler-Walters & Arnold, 2008).

Brosnan (1993) investigated the effect of trampling on an intertidal rocky shore area dominated by algae and barnacle assemblages in Oregon. The effects of 250 tramples per plot, once a month for a year were recorded. Abundances of algae in each plot were reduced from 80% to 35% within a month of the introduction of the pressure and remained low for the remainder of the experiment. As few as 20 steps / m^2 on stations on an intertidal rocky shore in the north-east of England were sufficient to reduce the abundance of fucoids (Fletcher & Frid, 1996a). This reduction in the complexity of the algae community, in turn, reduced the microhabitat available for epiphytic species. Trampling pressure can thus result in an increase in the area of bare rock on the shore (Hill *et al.*, 1998). Chronic trampling can affect community structure with shores becoming dominated by algal turf or crusts (Tyler-Walters, 2005). Pinn & Rodgers (2005) compared the biological communities found on two intertidal rocky shore ledges in Dorset. They found that the ledge which had a higher number of visitors had few branching algal species, including fucoids, but had greater abundances of crustose and ephemeral species (Pinn & Rodgers, 2005). The densities of fucoids were recorded from the intertidal rocky shore at Wembury, Devon in 1930 (Colman, 1933) and 1973 (Boalch *et al.*, 1974). Boalch *et al.* (1974) found a reduction in fucoids on the shore at Wembury compared to the abundances recorded by Coleman (1933).

The barnacles and limpets that contribute to LR.MLR.BF.PelB typically occur on the rock surfaces where they will be exposed to abrasion. Although limpets and barnacles are protected by hard shells or plates, abrasion may damage and kill individuals or detach these. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Removal of limpets may result in these being displaced to a less favourable habitat and injuries to foot muscles may prevent reattachment. Evidence for the effects of abrasion is provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles. The effects of trampling on barnacles appear to be variable with some studies not detecting significant differences between trampled and controlled areas (Tyler-Walters & Arnold, 2008). However, this variability may be related to differences in trampling intensities and abundance of populations studied. The worst case incidence was reported by Brosnan & Crumrine (1994) who reported that a trampling pressure of 250 steps in a 20 x 20 cm plot one day a month for a period of a year significantly reduced barnacle cover at two study sites. Barnacle cover reduced from 66% to 7% cover in 4 months at one site and from 21% to 5% within 6 months at the second site. Overall barnacles were crushed and removed by trampling. Barnacle cover remained low until recruitment the following spring. Long *et al.* (2011) also found that heavy trampling (70 humans / km shoreline) led to reductions in barnacle cover. Single step experiments provide a clearer, quantitative indication of sensitivity to direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victoria, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamalus antennatus* about 3 mm long), were crushed. However, on the same shore, the authors found that limpets may be relatively more resistant to abrasion from trampling. Following step and kicking experiments, few individuals of the limpet C*ellana tramoserica*, (similar size to *Patella vulgata*) suffered damage (Povey & Keough, 1991). One kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). Trampling may lead to indirect effects on limpet populations, Bertocci *et* *al. (*2011) found that the effects of trampling on *Patella* sp. increased the temporal and spatial variability of in abundance. The experimental plots were sited on a wave-sheltered shore dominated by *Ascophyllum nodosum*. On these types of shore, trampling in small patches, that removes macroalgae and turfs, will indirectly enhance habitat suitability for limpets by creating patches of exposed rock for grazing.

Sensitivity assessment. Fucoids are not tolerant of abrasion, and the effect of the pressure at this benchmark will cause a reduction in the abundances of *Pelvetia canaliculata*. Both barnacles and limpets are also negatively affected by trampling. Therefore the resistance is 'Low', the resilience is assessed as 'Medium'. Consequently, the sensitivity of this biotope has been assessed as 'Medium'.

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 this biotope group are epifauna or epiflora occurring on rock, which is resistant to subsurface penetration. Therefore, 'penetration' is **'Not relevant'**. The assessment for abrasion at the surface only is, therefore, considered to equally represent sensitivity to this pressure'. Please refer to 'abrasion' above.

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

In general, increased suspended particles may enhance food supply (where these are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). Very high levels of silt may clog respiratory and feeding organs of the suspension feeding barnacle species. In addition, increased turbidity will decrease light penetration reducing photosynthesis by macroalgae within this biotope. Increased levels of particles may increase scour and deposition in the biotope depending on local hydrodynamic conditions, although changes in substratum are assessed through the physical change (to another seabed type) pressure. *Pelvetia canaliculata* is found on the upper zone of intertidal rocky shores. Water depths within this part of the intertidal will never be great. So although an increase in turbidity at this pressure benchmark will increase light attenuation it is likely that light will still penetrate to the depth at which the algae are found. Allowing *Pelvetia canaliculata* to continue to photosynthesize whilst immersed. *Pelvetia canaliculata* spends as much as 90% of the time emersed (Fish & Fish, 1996). During this time the macroalgae can continue to photosynthesise unless environmental conditions become too severe (Beer & Kautsky, 1992).

A significant decrease in suspended organic particles may reduce food input to the biotope resulting in reduced growth and fecundity of barnacles. This would be most relevant to the LR.MLR.BF.PelB biotope. However, local primary productivity may be enhanced where suspended sediments decrease, increasing food supply.

Sensitivity assessment. This biotope is found on the upper intertidal shore and consequently is subject to long periods of emersion during which time macroalgae can continue to photosynthesize as long as plants have a sufficiently high water content. Therefore, photosynthesis and growth will not be greatly affected. Hence, the resistance and resilience of this biotope have been assessed as 'High', and the sensitivity of this biotope to this pressure, at the benchmark, is ‘Not Sensitive’.

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

A discrete event where sediment inundates this biotope to 5 cm will have different effects on the characterizing species depending on the state of the tide. During high tide, the characterizing species will be vertical in the water column. Any deposition at this state of the tide will mean that only a proportion of the stipe and holdfast will be covered. Fronds of *Pelvetia canaliculata* can reach up to 15 cm in length. Consequently, sediment deposition at high tide could leave up to 10 cm of *Pelvetia canaliculata* fronds sediment free. In contrast, if the tide is out, then fronds of the characterizing fucoid canopy will be flat on the substratum and will be smothered by the sediment deposit. The level of water flow caused by tidal movements and wave exposure within this biotope could remove from the shore within a few tidal cycles. There may be some decay of parts of the plants which are covered by the sediment. Germlings are likely to be smothered and killed regardless of the state of the tide and are inherently most susceptible to this pressure. Indeed early life stages are smaller in size than adults and are thus most vulnerable to this pressure as even a small load of added sediment will lead to the complete burial. Sediment deposition can reduce macroalgal recruitment by (1) reducing the amount of substratum available for attachment of propagules; (2) scour, removing attached juveniles and (3) burial, altering the light and/or the chemical micro-environment (Devinny & Volse, 1978, Eriksson & Johansson, 2003).

In New Hampshire, the lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by sand inundation (Daly & Mathieson, 1977). Field observations and laboratory experiments have highlighted the sensitivity of limpets to sediment deposition. Airoldi & Hawkins (2007) tested the effects of different grain sizes and deposit thickness in laboratory experiments using *Patella vulgata*. Sediments were added as a ‘fine’ rain to achieve deposit thicknesses of approximately 1 mm, 2 mm, and 4 mm in controlled experiments and grazing and mortality observed over 8-12 days. Limpets were more sensitive to sediments with a higher fraction of fines (67 % silt) than coarse (58 % sand). Coarse sediments of thicknesses approximately 1, 2 and 4 mm decreased grazing activity by 35, 45 and 50 % respectively. At 1 and 2 mm thicknesses, fine sediments decreased grazing by 40 and 77 %. The addition of approximately 4 mm of fine sediment completely inhibited grazing. Limpets tried to escape the sediment but lost attachment and died after a few days (Airoldi & Hawkins, 2007).

Sensitivity assessment. There is no empirical evidence for the effects of sediment inundation on *Pelvetia canaliculata*. Many fucoids, including *Ascophyllum nodosum* and *Fucus vesiculosus*, are intolerant of sediment. It is likely that *Pelvetia canaliculata* is also intolerant of sediment inundation for the same reasons, as the physical environment within which it is found does not require it to have a tolerance of this pressure. Many of the smaller species found within the biotope would be totally smothered by 5 cm. Experimentation has shown that sedimentation of 4 mm can cause mortality of *Patella vulgata* (Airoldi & Hawkins, 2007). The level of water movement within this biotope can be considerable and consequently deposited sediment will be removed within a small number of tides. This is likely to cause some damage to the characterizing species and the other associated species. Therefore, resistance and resilience have both been assessed as ‘Medium’. Overall the sensitivity of the biotope is assessed as ‘Medium’ at the level of the benchmark.

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

Several studies found that increasing the vertical sediment burden negatively impact fucoids survival and associated communities. At the level of the benchmark (30 cm of fine material added to the seabed in a single event) smothering is likely to result in mortalities of the characterizing species *Pelvetia canaliculata*. The maximum frond length of this species is 15 cm. The state of the tide would not change the effect of deposition at this benchmark. Even if deposition were to occur at high tide the fronds of *Pelvetia canaliculata* would be entirely covered. This inundation with sediment would inhibit photosynthesis, and would most likely lead to degradation of the macroalgae. Water movement within this biotope created by tidal streams and waves will remove sediment but it could take a number of tidal cycles. Filter feeding species such as the barnacles *Semibalanus balanoides* and *Chthalamus montagui* found in LR.MLR.BF.PelB would be entirely smothered, as would *Patella vulgata*. In this particular biotope, the level of water flow through tidal movement and wave exposure (exposed) could be high enough to remove the sediment relatively quickly. The level of sediment deposition would mean that this could take long enough to cause mortality of organisms.

Sensitivity assessment. Resistance is ‘Low ‘and resilience is ‘Medium’. Overall, the biotope has a ‘Medium’ sensitivity to siltation at the pressure benchmark.

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.

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

Species characterizing this habitat do not have hearing perception but vibrations may cause an impact. However, no studies exist to support an assessment.

Introduction of light or shading	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

Increased levels of diffuse irradiation correlate with increased growth in macroalgae (Aguilaria *et al.*, 1999). Levels of diffuse irradiation increase in summer, and with a decrease in latitude. As *Pelvetia canaliculata* is found in the middle its natural range in the British Isles an increase in the level of diffuse irradiation will not cause a negative impact on the species or the biotope. *Pelvetia canaliculata is likely to be affected by a decrease in light availability.*

Semibalanus balanoides sheltered from the sun grew bigger than un-shaded individuals (Hatton, 1938; cited in Wethey, 1984), although the effect may be due to indirect cooling effects rather than shading. Barnacles are also frequently found under algal canopies suggesting that they are tolerant of shading. Light levels have also been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoide*s. In general, light inhibits aspects of the breeding cycle. Penis development is inhibited by light (Barnes & Stone, 1972) while Tighe-Ford (1967) showed that constant light inhibited gonad maturation and fertilization. Davenport & Crisp (unpublished data from Menai Bridge, Wales, cited from Davenport *et al*., 2005) found that experimental exposure to either constant darkness, or 6 h light: 18 h dark photoperiods induced autumn breeding in *Semibalanus*. They also confirmed that very low continuous light intensities (little more than starlight) inhibited breeding. Latitudinal variations in the timing of the onset of reproductive phases (egg mass hardening) have been linked to the length of darkness (night) experienced by individuals rather than temperature (Davenport *et al*., 2005). Changes in light levels associated with climate change (increased cloud cover) were considered to have the potential to alter the timing of reproduction (Davenport *et al*., 2005) and to shift the range limits of this species southward.

Sensitivity assessment. It is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

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 – this pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit propagule dispersal. But propagule dispersal is not considered under the pressure definition and benchmark.

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 translocated. This pressure is therefore considered not relevant to this biotope.

Introduction or spread of invasive non-indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

There are no known invasive non-indigenous species in the British Isles that invade upper intertidal rocky shores where these biotopes and *Pelvetia canaliculata* are found. The Australasian barnacle *Austrominius* (previously *Elminius) modestus* was introduced to British waters on ships during the second world war. However, its overall effect on the dynamics of rocky shores has been small as *Austrominius modestus* has simply replaced some individuals of a group of co-occurring barnacles (Raffaelli & Hawkins, 1999). Although present, monitoring indicates it has not outnumbered native barnacles in the Isle of Cumbrae (Gallagher *et al*., 2015) it may dominate in estuaries where it is more tolerant of lower salinities than *Semibalanus balanoides* (Gomes-Filho, *et al*., 2010). The degree of wave exposure experienced by a biotope will limit colonization by *Austrominius modestus* which tends to be present in more sheltered biotopes. The higher wave exposures seen in the LR.MLR.BF.PelB biotope may not be suitable for this species of barnacle and are likely to limit its ability to compete with *Chthalamus montagui* and *Semibalanus balanoides.*

Sensitivity assessment. Fucoid species have been negatively affected by both the direct and indirect consequences of invasive non-indigenous species being present. However, no evidence can be found on the impacts of invasive non-indigenous species on *Pelvetia canaliculata* within this biotope. There is the possibility that For this reason the effect of this pressure has been given as ‘No Evidence’. Literature for this pressure should be revisited.

Introduction of microbial pathogens	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

There is insufficient evidence to support a review of the pressure at this benchmark. *Pelvetia canaliculata* is known to harbour a large number of micro-organisms on its outer surface (Rugg & Norton, 1987). A number of fungal species have also been found within the tissues of *Pelvetia canaliculata*, of which the ascomycetous fungi *Mycosphaerella ascophylli* is most commonly mentioned in literature (Subrahmanyan, 1960; Rugg & Norton, 1987). The interactions between this fungi and *Pelvetia canaliculata* are not fully understood. The number of microbial pathogens on *Pelvetia canaliculata* decreases in the summer. This is thought to be due to higher air temperatures causing mortality of pathogens (Rugg & Norton, 1987). Any introduction of microbial pathogen may be limited by the extreme physical conditions found within the habitat in which *Pelvetia canaliculata* is found.

Barnacles and the limpet *Patella vulgata* are considered subject to persistent, low levels of infection by pathogens and parasites. *Patella vulgata* has been reported to be infected by the protozoan *Urceolaria patellae* (Brouardel, 1948) at sites sheltered from extreme wave action in Orkney. Baxter (1984) found shells to be infested with two boring organisms, the polychaete *Polydora ciliate* and a siliceous sponge *Cliona celata.*

Sensitivity assessment. Based on the characterizing species and the lack of evidence for widespread, high-levels of mortality due to microbial pathogens it is considered that the sensitivity assessment of this biotope is ‘No evidence’.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. There is no evidence for the intertidal collection of *Pelvetia canaliculata*. Many intertidal microalgae's are harvested from the shore for both commercial and recreational purposes. The easy intertidal access to this species means that it would be easily collected from a shore. As the key characterizing and structuring species, extensive removal of *Pelvetia canaliculata* would alter the character of the biotope.

Patella vulgata is targeted for consumption and is found occasionally within the LR.MLR.BF.PelB biotope. However, it is not considered a characterizing species within this biotope and removal is unlikely to have an impact on the presence of the other characterizing species *Semibalanus balanoides* / *Chthalamus montagui* and *Pelvetia canaliculata.*

Sensitivity assessment. As no evidence for the harvesting of the characterizing species within this biotope the sensitivity assessment is considered to be 'Not relevant'.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The characterizing species *Pelvetia canaliculata* creates a dominant turf within this biotope. The dominance of this characterizing species means it could easily be incidentally removed from this biotope as by-catch when other species are being targeted. The loss of this species and other associated species would decrease species richness and negatively impact on the ecosystem function.

Sensitivity assessment. Removal of a large percentage of the characterizing species would alter the character of the biotope. The resistance to removal is 'Low' due to the easy accessibility of the biotopes location and the inability of these species to evade collection. The resilience is 'Medium', with recovery only being able to begin when the harvesting pressure is removed altogether. This gives an overall sensitivity score of 'Medium'.

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