Fucus ceranoides on reduced salinity eulittoral rock

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Fucus ceranoides **on reduced salinity eulittoral rock**
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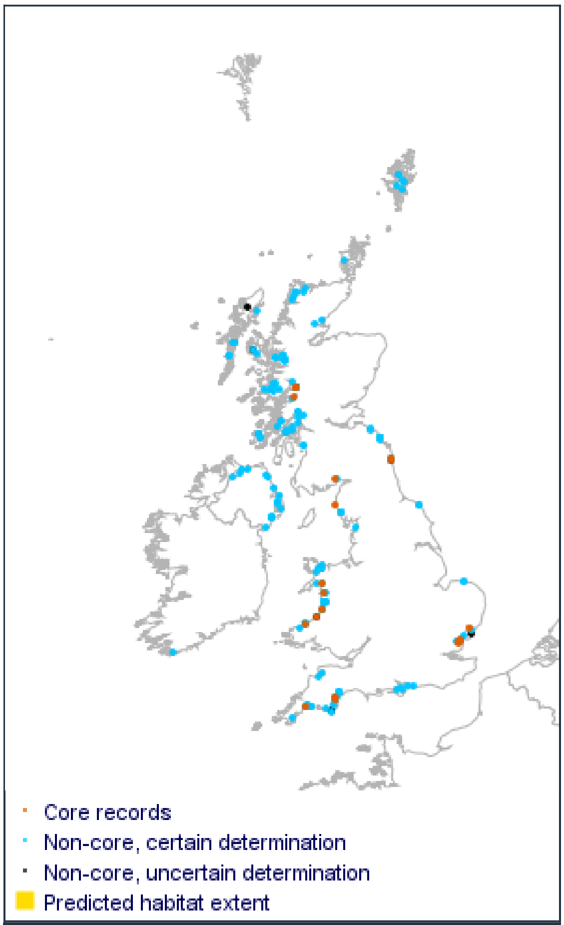

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Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

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

Summary

UK and Ireland classification

EUNIS 2008	A1.327	*Fucus ceranoides* on reduced salinity eulittoral rock
JNCC 2015	LR.LLR.FVS.Fcer	*Fucus ceranoides* on reduced salinity eulittoral rock
JNCC 2004	LR.LLR.FVS.Fcer	*Fucus ceranoides* on reduced salinity eulittoral rock
1997 Biotope	LR.SLR.FX.FcerX	*Fucus ceranoides* on reduced salinity eulittoral mixed substrata

Description

Very sheltered to extremely sheltered bedrock and stable boulders in the eulittoral zone that are subject to reduced salinity and characterised by the wrack *Fucus ceranoides*. Species richness is typically low in this biotope. The green seaweeds *Ulva intestinalis* and *Ulva lactuca* may be present together with the crab *Carcinus maenas* and the occasional barnacle *Austrominius modestus* and *Semibalanus balanoides*. *Fucus ceranoides* is more tolerant of reduced salinity than the other fucoids and tends to replace the wracks *Fucus spiralis*, *Fucus vesiculosus* and *Ascophyllum nodosum* towards the upper reaches of estuaries and sea lochs or in areas with freshwater influence. This biotope may, however, still contain other fucoids, although *Fucus ceranoides* always dominates. This biotope is often found on artificial substrata such as sea defences or bridge supports. (Information from Connor *et al*., 2004; JNCC, 2015).

Depth range

Upper shore, Mid shore, Lower shore

Additional information

The community includes fewer species when compared with open coast fucoid dominated shores. There are usually no limpets, or if present, occur only in very low numbers. Barnacles may occasionaly be present are predominantly *Semibalanus balanoides*, but *Austrominius modestus* is also present.

Listed By

- none -

Further information sources

Search on:

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Habitat review

Ecology

Ecological and functional relationships

- The biotope is characterized by fucoid seaweed species. At reduced salinities *Fucus ceranoides* is a superior competitor and tends to replace *Fucus vesiculosus*, *Fucus spiralis*, and *Ascophyllum nodosum* towards the upper reaches of estuaries and sea lochs. For instance, germlings of *Fucus ceranoides* developed from zygotes and grew at all salinities from 34 psu to 8.5 psu, whilst those of *Fucus vesiculosus* did not survive below 24 psu if germlings settled directly at reduced/low salinity. Growth of *Fucus ceranoides* (germlings and adult plants) was also faster than that of *Fucus vesiculosus* at all salinities from 17 psu downwards, but the pattern was reversed at full salinity (Khafaji & Norton, 1979). Furthermore, Lein (1984) considered that in addition to salinity stress, grazing by snails and heavy growth of epiphytes in higher salinity conditions confined *Fucus ceranoides* to estuarine environments.
- The presence of a fucoid canopy may inhibit the settlement of barnacles (*Semibalanus balanoides* and *Elminius modestus*) by blocking larval recruitment mainly by 'sweeping' the rock of colonizers. However, the canopy offers protection against desiccation which promotes the clumping of adults and the recruitment of young in several species of mobile animals, such as *Littorina littorea*.
- In feeding trials, the preferred food of *Littorina littorea* was small ephemeral seaweed, such as *Ulva* (Lubchenco, 1978), and the grazing activity of *Littorina littorea* may be important in keeping fast growing ephemeral species such as *Ulva* in check.
- Species within the biotope may act as hosts for parasite species. For instance, *Littorina littorea* hosts trematodes such as *Cryptocotyle lingua*, *Himasthla leptosoma*, *Renicola roscovita* and *Ceracaria lebourae*, whilst *Semibalanus balanoides* may be infested by the isopod *Hermioniscus balani*. Crisp (1960) recorded that 1.7 % of barnacles were infested by the isopod and that infested barnacles had no egg masses and grew nearly 40 % less than un-infested barnacles. King *et al.*, (1993) similarly recorded that 7 % of brooding *Semibalanus balanoides* were infested by the isopod.

Seasonal and longer term change

The biotope occurs in extremely sheltered conditions so dramatic temporal changes associated with winter storms are unlikely. However, seasonal changes in growth and recruitment are often apparent on rocky shores, influenced mainly by temperature and day length / degree of insolation. *Fucus ceranoides* communities may be more exposed to cold air and water temperatures than in locations next to the open sea. Germlings of *Fucus ceranoides* are found from the end of May to the beginning of August. Receptacles usually drop off by October or November. Some species may show spring seasonal changes, for instance, in northern Britain *Littorina littorea* migrates down shore as temperatures fall in autumn (to reduce exposure to sub-zero temperatures) and up shore as temperatures rise in spring; migration depends on local winter temperatures.

Habitat structure and complexity

The beds of fucoids in the biotope increase the structural complexity of the habitat providing a variety of resources that are not available on bare rock. Fronds provide space for attachment of encrusting or sessile epifauna and epiphytic algae and provide shelter from wave action, desiccation and heat for invertebrates.

Productivity

Rocky shore communities are highly productive and are an important source of food and nutrients for members of neighbouring terrestrial and marine ecosystems (Hill *et al.*, 1998). Macroalgae exude considerable amounts of dissolved organic carbon which are absorbed readily by bacteria and may even be taken-up directly by some larger invertebrates. Only about 10% of the primary production is directly cropped by herbivores (Raffaelli & Hawkins, 1996). Dissolved organic carbon, algal fragments and microbial film organisms are continually removed by the sea. This may enter the food chain of local, subtidal ecosystems, or be exported further offshore. Rocky shores make a contribution to the food of many marine species through the production of planktonic larvae and propagules which contribute to pelagic food chains.

Recruitment processes

- Many rocky shore species, plant and animal, possess a planktonic stage: gamete, spore or larvae which float in the plankton before settling and metamorphosing into adult form. This strategy allows species to rapidly colonize new areas that become available. For these organisms it has long been evident that recruitment from the pelagic phase is important in governing the density of populations on the shore (Little & Kitching, 1996). Hence, both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates.
- The propagules of most seaweeds have little or no control over their destination. When released into the sea, they are distributed by waves and currents. Clearly to disperse beyond the zone that they will be able to inhabit is wasteful of propagules, and some intertidal plants seem able to limit dispersal to a meter or so (Dayton, 1973; Deysher & Norton, 1982). Propagules of *Fucus* species can colonize up to at least 23 m from the parent plants on a shore devoid of seaweeds (Burrows & Lodge, 1950).
- *Littorina littorea* can breed throughout the year but the length and timing of the breeding period are extremely dependent on climatic conditions. Estuarine locations, where this biotope may be found, provide a more nutritious environment than the open coast (Fish, 1972). Sexes are separate, and fertilisation is internal. *Littorina littorea* sheds egg capsules directly into the sea and egg release is synchronized with spring tides, on several separate occasions. In estuaries the population matures earlier in the year and maximum spawning occurs in January. Fecundity value is up to 100,000 for a large female (27mm shell height) per year. Female fecundity increases with size. Larval settling time or pelagic phase can be up to six weeks. Males prefer to breed with larger, more fecund females. Parasitism by trematodes may cause sterility.
- Barnacle recruitment can be very variable because it is dependent on a suite of environmental and biological factors, such as, wind direction, temperature, latitude, light, feeding, age, size, crowding, seaweed cover and pollution and success depends on settlement being followed by a period of favourable weather. High shore *Semibalanus balanoides* breed first and low shore specimens last (up to 12 days difference) (Barnes, 1989). Fertilization is prevented by temperatures above 10 °C and continuous light. Differences in breeding times with latitude are probably mediated by temperature and day length, e.g. in Spitzbergen fertilization occurs 2-3 months earlier than in the United Kingdom. Release of *Semibalanus balanoides* larvae takes place between February and April with peak settlement between April and June. The barnacle *Elminius modestus* is a cross-fertilizing hermaphrodite which breeds almost continuously throughout the year.

Under favourable conditions it has been known for broods to be released every 10 days. Cyprid larvae are found on the shore between May and October. Newly metamorphosed *Elminius modestus* grow rapidly and can reach maturity in about eight weeks (Fish & Fish, 1996).

Time for community to reach maturity

Fucoid species are found on all British and Irish coasts so there are few mechanisms isolating populations. With the exception of *Ascophyllum nodosum*, fucoids are highly fecund, iteroparous, surviving and breeding for protracted periods over 3-4 years. The eggs are broadcast into the water column allowing a potentially large dispersal distance. Green algal species such as *Ulva* are opportunistic ephemeral species that can recruit rapidly when conditions are suitable and will often be the early colonizers of areas that have been disturbed. *Littorina littorea* generally reaches maturity between two or three years of age, when shell height is about 12 mm, and the species can live for five or more years (Fish & Fish, 1996). The barnacle, *Semibalanus balanoides*, grows rapidly in the first season after settlement. Its newly metamorphosed larvae are very squat and only form the adult shape at 3 mm. *Semibalanus balanoides* may become sexually mature in the first year after settlement although this is often delayed until 2 years of age (Anderson, 1994). The lifespan of *Semibalanus balanoides* varies with the position on the shore. Barnacles low on the shore typically die in their third year, whereas those from near the mean level of high water neaps may live for five or six years. Therefore, the community to reach maturity is likely to reach maturity within five years (in terms of the presence of characterizing species and those species being sexually mature), although development of a stable community structure may take a little longer due to competitive interactions.

Additional information

No text entered.

Preferences & Distribution

Habitat preferences

Depth Range	Upper shore, Mid shore, Lower shore
Water clarity preferences	Field Unresearched
Limiting Nutrients	Nitrogen (nitrates)
Salinity preferences	Reduced (18-30 psu), Variable (18-40 psu)
Physiographic preferences	Enclosed coast / Embayment
Biological zone preferences	Lower littoral fringe, Upper eulittoral, Upper littoral fringe
Substratum/habitat preferences	Artificial (man-made), Bedrock, Cobbles, Gravel / shingle, Large to very large boulders, Mixed, Mud, Pebbles, Small boulders
Tidal strength preferences	Moderately Strong 1 to 3 knots (0.5-1.5 m/sec.), Very Weak (negligible), Weak < 1 knot (<0.5 m/sec.)
Wave exposure preferences	Extremely sheltered, Very sheltered

Other preferences

Additional Information

Nitrogen is the primary resource that limits seaweed growth and consequently variations in seaweed growth should parallel variations in the nitrogen supply (Lobban & Harrison, 1997).

Species composition

Species found especially in this biotope

- *Fucus ceranoides*

Rare or scarce species associated with this biotope

-

Additional information

No text entered

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The description of this biotope and the information on the characterizing species is taken from Connor *et al.* (2004). The LR.LLR.FVS.Fcer biotope is found in reduced salinity conditions in the upper sections of estuaries. The salinity regime within this biotope makes it suitable for *Fucus ceranoides*, whose entire life cycle is adapted to tolerate low salinities. As a result, other species of fucoid can't compete within the same habitat. *Fucus ceranoides* is susceptible to high levels of grazing from littorinids (Norton, 1986). However, the salinity conditions within this biotope mean that littorinids are rare, allowing *Fucus ceranoides* to dominate. The biological community within this biotope is sparse and many of the other species have life histories which make them opportunistic and short lived. Such species include *Ulva lactuca* and *Ulva intestinalis*, as well as multiple amphipod species. There are also two species of barnacle found within this biotope; *Seimbalanus balanoides* and *Austrominius* (was *Elminius*) *modestus*. *Fucus ceranoides* is the only characterizing species within the biotope, as the loss of the species would result in the loss of the biotope. Other species contribute to the composition of the biotope but are not crucial to the presence of *Fucus ceranoides*.

Resilience and recovery rates of habitat

Recolonization of *Fucus* dominated areas took between one to three years in British waters and was especially rapid in areas cleared of grazers (Hartnoll & Hawkins, 1985; Hawkins & Hartnoll, 1985). The lack of fucoid grazers is notable within this biotope. The relatively short lifespan of *Fucus ceranoides*, 3 – 5 years (Lein, 1984; Brawley, 1992, Bäck *et al.*, 1992), and annual reproduction would allow this species to recolonize quickly. If recruitment was good, it is conceivable that a mature stand of *Fucus ceranoides* could be present within 3 years. Fucoids don't have a planktonic dispersal stage and consequently, their dispersion capacity above 50 m is minimal (Chapman, 1995; Serrão *et al.*, 1997; Dudgeon *et al.*, 2001; taken from Neiva *et al.*, 2012). In addition to a low dispersal capacity, *Fucus ceranoides* is found in relatively small and isolated populations in intertidal estuarine areas (Neiva *et al.*, 2012). Sperm in fucoids has a greater dispersal capacity (>10 m) than eggs (<0.5 m) (Serrão *et al.*, 1997). Therefore, if there were to be a case of inter-estuary gamete fertilization within *Fucus ceranoides* it is more likely to be the sperm contributing to the gene flow (Neiva *et al.*, 2012). Yet the short lifespan, sensitivity to changes in salinity, and the effect of dilution would limit the reach of *Fucus ceranoides* sperm (Serrão *et al.*, 1996). A mass mortality event of *Fucus ceranoides* within an estuary due to high sensitivity to a pressure would require the long distance transport of drifting fertile fronds for recovery to occur (Neiva *et al.*, 2012). Neiva *et al.*, (2012) deduced that this must have been the only mechanism via which *Fucus ceranoides* was able to recolonize northern Europe since the last Ice Age. There are no documented examples of this but it is reasonable to assume that the frequency of a successful relocation to a new estuary is low.

Unlike many intertidal rocky shore communities, the species list for this biotope does not have a dominant grazing species. *Littorina littorea* is a dominant grazer on many intertidal rocky shores where salinity regimes are either full (30 – 40 psu) or variable (18 – 40 psu) (Connor *et al*., 2004). However, in lab experiments, *Littorina littorea* grazing activity is significantly reduced below salinities of 17% (Norton, 1986). In the Firth of Clyde the seaward limit of *Fucus ceranoides* coincides with the inland limit of littorinids (Norton, 1986). In the field, *Littorina littorea* is replaced by amphipods as the dominant mesograzer when salinities regularly fall below 12% (Johannesson *et al*., 1988). The main grazers present within this biotope are amphipods, presumably, because the reduced salinity (18 – 30 psu) regime is not suitable for Littorinids. Amphipods often eat epiphytic species that grow on macroalgaes rather than the macroalgaes themselves (Little & Kitching, 1996). Eriksson *et al.* (2011) found that although amphipods may not directly consume macroalgae, they can control macroalgal biomass. Strong predation on amphipods within the *Fucus vesiculosus* habitat did not change macroalgae biomass. This was due to omnivorous shrimps grazing the macroalgae when their main food source i.e. the amphipods were removed. Thus preventing a trophic cascade and a change in the biotope. Within this biotope, amphipods are not being assessed as the dominant grazer as evidence suggests that they do not directly graze the characterizing species. Predicting how species, such as omnivorous shrimps, may indirectly affect this biotope when immersed is difficult because these species are not considered in intertidal biotopes. However, any pressure which may cause significant changes in the abundance in amphipods and could have a negative impact on the biotope will be taken into consideration when assessing the effects of pressures. Amphipods are associated with a number of ephemeral intertidal biotopes such as LS.LSa.St.Tal and LS.LSaMoSa.AmSco (Connor *et al*., 2004). Many species of amphipod have short life histories, and some recruit twice per annum (Fish & Preece, 1970)

Both *Ulva* (was *Enteromorpha*) *intestinalis* and *Ulva lactuca* are classified as opportunistic species that are able to rapidly colonize newly created gaps across a range of sediment types, shore heights, wave exposures and salinity regimes. The life history characteristics that support this opportunism are the broad tolerances for a wide range of conditions (Vermaat & Sand-Jensen, 1987) and high growth and reproduction rates. *Ulva intestinalis* is amongst the first multicellular algae to appear on substrata that have been cleared following a disturbance, e.g. following the Torrey Canyon oil spill in March 1967, species of the genus *Ulva r*apidly recruited to areas where oil had killed the herbivores that usually grazed on them, so that a rapid greening of the rocks (owing to a thick coating of *Ulva* spp.) was apparent by mid-May (Smith, 1968). The rapid recruitment of *Ulva* sp. to areas cleared of herbivorous grazers was also demonstrated by Kitching & Thain (1983). Following the removal of the urchin *Paracentrotus lividus* from areas of Lough Hyne, Ireland, *Ulva* grew over the cleared area and reached 100% coverage within one year. Such evidence suggests that these species will rapidly return to this biotope.

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*. Biological factors such as larval supply, competition for space, the 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 balanoides* dying within ten days (Kendall *et al*., 1985). Presumably, these factors would also influence the transport, supply and settlement of *Austrominius* (was *Elminius*) *modestus*.

Resilience assessment. This biotope is characteristically low in biodiversity, and the species which contribute to the biological community are often ephemeral and short lived. Except for the characterizing species *Fucus ceranoides* many of the species, including *Ulva* sp., barnacles have planktonic stages which allow for significant dispersal capabilities. If a pressure were to reduce the abundance of *Fucus ceranoides*, the species would be able to recruit from the remaining population and a return to a mature stand could occur within three years. The return of the remaining biological community and previous ecological function would be quick due to the ephemeral and opportunistic character of the species. For pressures where some *Fucus ceranoides* population remains resilience is assessed as 'Medium'. However, for pressures where the benchmark level would cause complete removal of *Fucus ceranoides*, a resilience of 'Low' is given.

Hydrological Pressures

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

Populations of *Fucus ceranoides* are restricted to estuaries, but examples this biotope are found throughout estuaries in the British Isles. The distribution of *Fucus ceranoides* in the north east Atlantic extends from northern Norway (Lein, 1984) to the River Mondego in Portugal (Neiva *et al*., 2012). 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. Growth rates in *Fucus ceranoides* have not been recorded, and there is no empirical evidence on the upper and lower temperature tolerances. *Fucus ceranoides* occur from high to low shore (depending on locality) (Connor *et al*., 2004; physical comparative tables). This range in location on the shore suggests that *Fucus ceranoides* can tolerate a range of temperatures. Fertilization at extremely high (25 °C) temperatures can only occur in full salinity (Burrows, 1964).

Ulva sp. are distributed globally (Guiry & Guiry, 2015 and references therein) and occur in warmer waters than those surrounding the UK suggesting that they can withstand increases in temperature at the pressure benchmark. *Ulva* sp. are characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shore heated to 27-30 °C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al*., 1976).

Although adults may be able to withstand acute and chronic increases in temperature at the pressure benchmark, increased temperatures may have sub-lethal effects on the population through impacts on reproduction. The distribution of *Semibalanus balanoides* is 'northern' with their range extending to the Arctic circle. Populations in the southern part of England are relatively close to the southern edge of their geographic range. Long-term time series show that successful recruitment of *Semibalanus balanoides* is correlated to sea temperatures (Mieszkowska, *et al*., 2014) and that due to recent warming its range has been contracting northwards. Increased temperatures are likely to favour chthamalid barnacles or *Austrominius modestus* in the sheltered variable salinity biotopes rather than *Semibalanus balanoides* (Southward *et al*. 1995).

Sensitivity assessment. An increase in temperature at the pressure benchmark may cause some *Fucus ceranoides* to die off at the top of the shore due to increased levels of desiccation caused by higher temperatures, especially during the summer months. However, it will not cause large losses of the characterizing species. *Ulva* sp. are resistant to high temperatures and are very quick to recolonize. Examples of the biotope in a more southerly location may see an increase in the number of *Austrominius modestus* and a decrease in *Semibalanus*. This is unlikely to cause any significant changes in the biotope as the functional niche will still be filled. Both resistance and resilience have been assessed as 'High', meaning the biotope is 'Not sensitive' to an increase in temperature at the pressure benchmark.

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

Populations of *Fucus ceranoides* are restricted to estuaries, but examples this biotope are found throughout estuaries in the British Isles. The distribution of *Fucus ceranoides* in the north east Atlantic extends from northern Norway (Lein, 1984) to the River Mondego in Portugal (Neiva *et al*., 2012). 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. Growth rates in *Fucus ceranoides* have not been recorded, and there is no empirical evidence on the upper and lower temperature tolerances. This biotope is occasionally found on the low shore (17.65%) but is almost as common on the upper shore (52.94%) as it is on the mid shore (47.06%) (Connor *et al*., 2004; physical comparative tables). This range in location on the shore suggests that *Fucus ceranoides* can tolerate a range of temperatures. Fertilization at extremely low (2 °C) temperatures can only occur in full salinity (Burrows, 1964). At a water temperature of 10 °C fertilization is entirely inhibited below 8 ppt (Burrows, 1964).

Ulva intestinalis and *Ulva lactuca*, occur in Arctic regions and Alaska and are therefore found in colder waters than those around the UK (Guiry & Guiry, 2015 and references therein), *Ulva* sp. (as *Enteromorpha*) were reported to be tolerant of a temperature of -20 °C (Kylin, 1917). Vermaat & Sand-Jensen (1987) found that rapid deep freezing of *Ulva lactuca* collected in Roskilde Fjord, Denmark killed the plants. However, individuals from the same area when collected from frozen ice, survived and resumed growth, the plants are able to survive more gradual natural freezing (Vermaat & Sand-Jensen, 1987).

The tolerance of *Semibalanus balanoides* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance was -14.6 °C (Davenport & Davenport, 2005). A decrease in temperature at the pressure benchmark is, therefore, unlikely to negatively affect this species.

Sensitivity assessment. A decrease in temperature at the pressure benchmark is not likely to have a significant effect on *Fucus ceranoides*. There may be some decrease in growth rate, and a greater effect of winter temperatures. However, it will not cause large die backs of the characterizing species. *Ulva* sp. are resistant to low temperatures and are very quick to recolonize. Examples of the biotope in a more southerly location may see a decrease in the number of *Austrominius modestus* and an increase in *Semibalanus*. This is unlikely to cause any significant changes in the biotope as the functional niche will still be filled. Both resistance and resilience have been assessed as 'High', meaning the biotope is 'Not sensitive' to an increase in temperature at the pressure benchmark.

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

Species found in the intertidal are likely to have some form of behavioural or physiological adaptations to changes in salinity. *Fucus ceranoides* can grow and become fertile between salinities of 7 – 34 ppt (Burrows, 1964). Its optimal salinity for growth rate is 16 ppt, however, successful fertilization occurs most commonly at full salinities (Burrows, 1964). The eggs of *Fucus ceranoides* can tolerate immersion in freshwater within 2 hours of release (Burrows, 1964). Germlings and excised tips of *Fucus ceranoides* develop tissue damage and decay in full salinity water (Khfaji & Norton, 1979). If *Fucus ceranoides* is subject to fully marine conditions it decays within a few months (Khfaji & Norton, 1979; Suryono & Hardy, 1997). The evidence suggests that the fluctuation in salinity is important to the survival of *Fucus ceranoides*. And even if *Fucus ceranoides* was able to tolerate fully marine conditions, it is unlikely to survive as it grows slower than other fucoids such as *Fucus vesiculosus* (Khfaji & Norton, 1979) and would be out-competed for space. An increase in the salinity regime would also mean that the habitat would become suitable for littorinids. This grazing species has a significant negative impact on *Fucus ceranoides* through grazing (Norton, 1986), and can completely remove *Fucus ceranoides* as the macroalga doesn't have any mechanism to deter it.

Ulva sp. can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variations in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime.

Semibalanus balanoides is tolerant of a wide range of salinities and has the ability to isolate themselves 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*., 2001). Barnes & Barnes (1974) found that larvae from *Semibalanus (as Balanus) balanoides*, complete their development to nauplii larvae at salinities between 20-40%.

Sensitivity assessment. An increase in salinity at the benchmark within this biotope would have a negative impact on the health and reproductive capacity of *Fucus ceranoides*. The change would lead to other intertidal fucoids, such as *Fucus serratus* and *Fucus vesiculosus*, recruiting into the habitat. These species will out-compete *Fucus ceranoides* consequently forcing them from the shore and removing the biotope. The increase in salinity will also mean that littorinid grazers would move into the habitat and begin grazing. It is likely that species richness will rise as the substratum would probably to colonized by marine species which were previously excluded by an intolerance to reduced salinity. Resistance has been assessed as 'Low' as the change in salinity at the benchmark would lead to *Fucus ceranoides* being both grazed and out-competed by species with a greater tolerance to salinity. The resilience is assessed as 'Medium' resulting in 'Medium' sensitivity.

Salinity decrease (local)	Medium Q: High A: High C: Medium	Medium Q: High A: Medium 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 are therefore likely to have some form of behavioural or physiological adaptations to changes in salinity. *Fucus ceranoides* can grow and become fertile between salinities of 7 – 34 ppt (Burrows, 1964). Its optimal salinity for growth rate is 16 ppt, however, successful fertilization occurs most commonly at high salinities (Burrows, 1964). The eggs of *Fucus ceranoides* can tolerate immersion in freshwater within 2 hours of release (Burrows, 1964). Germlings and excised tips of *Fucus ceranoides* develop tissue damage and decay in full salinity water (Khfaji & Norton, 1979). A decrease in salinity would lead to a low salinity (<18 ppt) (Connor *et al*., 2004). Low salinity would decrease the success rates of fertilization, but would still allow *Fucus ceranoides* to survive.

Ulva sp. can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Variations in salinity tolerance in populations of *Ulva intestinalis* have been found suggesting that plants have some adaptation to the local salinity regime. Alströem-Rapaport *et al*., (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which was considered to partly explain the high rates of colonisation and adaptability of the species. Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell, 1979). For example; eulittoral zone material showed decreased percentage regeneration in all salinities (dilute: 0, 4.25, 8.5, 17 & 25.5 psu, and concentrated seawater: 51, 68, 95, 102 & 136 psu) except 34 psu, when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). None of the eulittoral zone material was able to regenerate in freshwater or concentrated seawater, whilst littoral fringe and rock pool material was able to do so.

Semibalanus balanoides is tolerant of a wide range of salinities and has the ability to isolate themselves 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*., 2001). Barnes & Barnes (1974) found that larvae from *Semibalanus (as Balanus) balanoides*, complete their development to nauplii larvae at salinities between 20-40%.

Sensitivity assessment. A decrease in salinity at the benchmark within this biotope would reduce the fertilization success of *Fucus ceranoides*, but would still allow growth and reproduction. Other species in the biotope would still be able to survive for some time at low salinities, but their abundance would reduce over the year, and they may die back altogether. When the salinity regime returned to normal (reduced / variable), species such as *Semibalanus balanoides* and *Ulva* sp. would return quickly. Resistance has been assessed as 'Medium', as has the resilience, resulting in the biotope having a 'Medium' sensitivity to this pressure at the benchmark level.

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

This biotope is found in moderately strong – very weak (1.5 m/sec. - negligible) conditions. However, the characterizing species *Fucus ceranoides* is limited to the salinity regimes found within estuaries, environments which also happen to have these water flow conditions. Therefore, the level of water flow experienced within the biotope may only be a factor of the physical environment and not a limiting factor for the species. No empirical evidence is available on water flow tolerances in *Fucus ceranoides.* An investigation into *Fucus spiralis* (a species whose fronds reach a maximum length comparable to that of *Fucus ceranoides*) found that plants were torn from their anchorage at7 – 8 m/sec (Jonsson *et al*., 2006). Even if water flows an increase in water flow didn't directly remove adults from the substrata, it could have an impact on dispersal, fertilization, settlement and recruitment (Pearson & Brawley, 1996).

Both *Ulva intestinalis* and *Ulva lactuca* are flexible and conform to the direction of the flow reducing drag and breakage. However, experimental studies show that exposure to currents results in sloughing of tissue and higher current velocities result in breakage of the thallus. Kennison & Fong (2013) found that *Ulva intestinalis*, settled on ceramic tiles and deployed in the field were subject to greater losses at mean flow speeds of 0.2 m/s (approximately 16 % of biomass) than the 8 % loss from individuals subject to lower flows (0.15 m/s). Increased water velocities can enhance recruitment through increased larval supply (Kennison & Fong, 2013). Houghton *et al.* (1973) observed that swarmers of *Ulva* were able to settle onto surfaces subjected to water speeds of up to 10.7 knots, suggesting that changes may not inhibit settlement.

Growth and reproduction of *Semibalanus balanoides* are 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). 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 as they can adapt to a variety of flow speeds.

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

Emergence regime is a key factor structuring intertidal biotopes. Within this biotope *Fucus ceranoides* is found from the upper intertidal, down to the lower shore, where it is most sparse (Connor *et al.*, 2004; Physical comparative tables). A change in emergence would lead to a shift in the area covered by *Fucus ceranoides* and this biotope. However, the presence of this biotope at all shore heights will allow the biotope to persist throughout.

Ulva sp. lose their water content very fast, but overcome the problem by growing in dense populations where they can cover and shade each other to some extent when exposed. As *Ulva intestinalis* is able to tolerate dessication stress it is often very abundant on the high shore where desiccation stress is the primary factor controlling seaweed distribution, and may even be found above the tidal limits of the shore. *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can survive several weeks of living in completely dried out rock pools, while becoming completely bleached on the uppermost layers, but remaining moist underneath the bleached fronds. However, dessication stress of germlimgs may be lower than adults Hruby & Norton (1979) found that 7-14 day old germlings of *Ulva* (studied as *Enteromorpha*) were more tolerant of desiccation than earlier stages, so an increase in desiccation stress resulting from increased emergence may impact more adversely on newly settled germlings than more mature plants.

A change in emergence would alter the feeding time and increase desiccation for barnacles within the biotope. *Semibalanus balanoides* is less tolerant of desiccation stress than other barnacle species. If emergence were to change, there may be a shift in barnacle species within the biotope. However, if the barnacle species were to change the functional niche would still be filled leading to the biotope remaining.

Sensitivity assessment. This biotope extends from the high shore through to the low shore (Connor *et al.*, 2004). If there was a decrease in emergence then the lower limit of the biotope would shift up the shore. However, if there was an increase in emergence the top part of the biotope would be lost and the biotope would shift down the shore. The physiological tolerances of *Fucus ceranoides* would not be able to tolerate the changes in physical factors associated with the change in emergence. Therefore, resistance is assessed as 'Medium' as some of the biotope would be lost. However, the remaining *Fucus ceranoides* would provide a mature stand from which the shore could recolonise quickly. This means the resistance is also 'Medium', giving the biotope a sensitivity of 'Medium'.

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

This biotope is found in very sheltered to extremely sheltered conditions. However, the characterizing species *Fucus ceranoides* is limited to the salinity regimes found within estuaries, environments which also happen to have these wave exposures. Therefore, wave exposures experienced within the biotope may only be a factor of the physical environment and not a limiting factor for the biological despecies. No empirical evidence is available on wave exposure tolerances in *Fucus ceranoides*. However, the water flows experienced within this biotope (very weak to moderately strong (Connor *et al*., 2004) suggest that an increase in wave exposure would not have a negative impact on the characterizing species. The remaining species within this biotope are found within other biotopes where wave exposure exceeds that found within this biotope.

Sensitivity assessment. At the benchmark this biotope is 'Not Sensitive' to a change in wave exposure. This means that both resistance and resilience are 'High'.

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

The biotope in question occurs in the eulittoral and consequently, a 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. This biotope is found in very sheltered to extremely sheltered and the moderately strong to negligible tidal flows, consequently water mixing is not very strong. Therefore, water movement within this area will not reverse any oxygen depletion quickly, possibly exacerbating any negative effects.

Sensitivity assessment. The characterizing species *Fucus ceranoides* and other species present within this biotope require oxygen for respiration. The intertidal position of this biotope means that all species spend periods of time emersed, where oxygen is not limited. This is advantageous for algae and can allow them to continue to photosynthesis and respire. However, this is not the case for barnacles as they need to be immersed to obtain oxygen. Barnacles appear are able to respire anaerobically for some time and consequently some individuals may be able to survive the pressure at this benchmark. Resistance is assessed as ‘High’. Resilience is assessed as ‘High’, giving the biotope a sensitivity score of ‘Not sensitive’.

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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. 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).

No direct evidence was found to assess the effect of this pressure on this biotope. A slight increase in nutrient levels could be beneficial for barnacles by promoting the growth of phytoplankton levels and therefore increasing zooplankton levels. However, Holt *et al*. (1995) predict that smothering of barnacles by ephemeral green algae is a possibility under eutrophic conditions.

Opportunistic algae, including *Ulva* sp.,a contaminants can’t store nutrients in the thallus (unlike larger, long-lived species) and are adapted to efficiently capture and utilise available nutrients in the water column (Pedersen *et al*., 2009). A large body of field observations and experiments, surveys and laboratory experiments confirm that *Ulva* sp., can utilise high levels of nutrients for growth (Martínez *et al*., 2012) and that enhanced recruitment (Kraufvelin *et al*., 2007) and growth of this genus can occur in enriched areas (Kennison & Fong, 2013; Vaudrey *et al*., 2010). In areas where nutrient availability is lower either naturally or through management to reduce anthropogenic inputs, *Ulva* sp. may be negatively affected through reduced growth rate and species replacement (Martínez *et al*., 2012; Vaudrey et al., 2010).

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 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 was '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 aquaculture or sewage 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 *et al.*, 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 *et al*, 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 *et al.*, 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. 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: High A: Medium C: Medium	Medium Q: High 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 was '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 aquaculture and sewage on intertidal rocky shores often led 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 *et al*., 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 *et al.*, 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 *et al.*, 2006b; Kraufvelin *et al.*, 2007).

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. The contribution of *Ulva* sp. to the biological community within this biotope means that if conditions were to become more favourable for this species it could easily increase in abundance. An increase in this species could over grow the slower growing characterizing species *Fucus ceranoides.* 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 and boulders on which the associated biological community attach. 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 *Fucus ceranoides* along with other species associated with this biotope. Resistance is assessed as ‘None’. As this pressure represents a permanent change, recovery is impossible as a suitable substratum for the biological community of this biotope is lacking. Consequently, resilience is assessed as ‘Very Low’. The habitat 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 this biotope which occurs predominantly on bedrock (Connor *et al*., 2004).

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

Trampling on the rocky shore has been observed to reduce fucoid cover which decreased the microhabitat available for epiphytic species, increased bare space and increased cover of opportunistic species such as *Ulva* sp. (Fletcher & Frid, 1996a). This biotope is found on the intertidal shore, an area easily accessible by humans especially at low tide. Individual macroalgae 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). 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 that 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).

No direct evidence was found to assess how *Ulva* spp. respond to surface abrasion. The fronds are very thin and could be torn and damaged and individuals may be removed from the substratum, altering the biotope through changes in abundance and biomass. *Ulva* spp. cannot repair damage or reattach but torn fronds could still photosynthesise and produce gametes. Tearing and cutting of the fronds have been shown to stimulate gamete production and damaged plants would still be able to grow and reproduce. Therefore, damage and removal may not lead to mortality of impacted individuals. *Ulva* spp. can also form unattached mats, particularly in response to nutrient enrichment.

The barnacles which contribute to this biotope typically occur on the rock surfaces where they will be exposed to abrasion. Although 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. Evidence for the effects of abrasion are 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^{-1} shoreline h^{-1}) 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.

Sensitivity assessment. Fucoids are not tolerant of abrasion, and the effect of the pressure at this benchmark is very likely to cause a decrease in abundance of *Fucus ceranoides*. Barnacles are also negatively affected by trampling. Therefore, the resistance is ‘Low’; the resilience is assessed as ‘Medium’. Consequently, the sensitivity of this biotope to abrasion has been assessed as ‘Medium’.

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

The characterizing species of this biotope occurs on rock which is resistant to subsurface penetration. The assessment for abrasion at the surface only is therefore considered to equally represent sensitivity to this pressure.

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

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. *Fucus ceranoides* is found within all zones 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. Those examples of *Fucus ceranoides* found on the lower shore may be mildly affected by this and may experience a slight decrease in growth rate, however, there is no empirical evidence for this. A decrease in SPM could is unlikely to have a negative impact on the 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.

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

Sensitivity assessment. At this pressure benchmark resistance and resilience of this biotope has been assessed as ‘High’. The sensitivity of this biotope to this pressure at the benchmark is ‘Not Sensitive’.

Smothering and siltation rate changes (light)	Medium Q: Low A: NR C: NR	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 *Fucus ceranoides* are between 30 – 60 cm in length (Bunker *et al.*, 2012). Consequently, sediment deposition at high tide could leave a proportion of *Fucus ceranoides* 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. There is no empirical evidence to suggest how smothering effects *Fucus ceranoides.* However, it may be assumed that inundation with sediment will reduce gaseous exchange limiting the macroalga's ability to photosynthesise and respire. Without the ability to carry out these two functions fronds will become damaged and consequently die. Due to the lack of information on this, timescales for this process are not available. Moderately strong water flows caused by tidal movements within this biotope could remove from the shore within a few tidal cycles. Germlings are likely to be smothered and killed regardless of the state of the tide and are inherently most susceptible to this pressure. 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).

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen , (1987) exposed thallus discs (113 mm^2) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987).

Although *Ulva* sp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggests that resistance to this pressure may be lower.

Semibalanus balanoides and *Austrominius* modestus are likely to be negatively affected by siltation. The lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear. Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit grazing and result in loss of attachment and death after a few days (Airoldi & Hawkins, 2007).

Sensitivity assessment. Within this biotope, there is some water flow from tides and currents which can reach moderately strong (1.5 m/sec.) (Connor *et al*., 2004). This water movement will allow the deposited sediment to be washed away relatively quickly. However, sediment may still be present long enough to cause damage to the fronds of *Fucus ceranoides* and the other species within this biotope. For this reason, resistance has been assessed as ‘Medium’, as has the resilience. The sensitivity of this biotope is, therefore, also ‘Medium’.

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

A discrete event where sediment inundates this biotope to 30 cm would cover all species with a thick layer of fine materials. 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 *Fucus ceranoides* are between 30 – 60 cm in length (Bunker *et al*., 2012). Consequently, sediment deposition at high tide could leave a proportion of *Fucus ceranoides* 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. There is no empirical evidence to suggest how smothering effects *Fucus ceranoides*. However, it may be assumed that inundation with sediment will reduce gaseous exchange limiting the macroalga's ability to photosynthesise and respire. Without the ability to carry out these two functions fronds will become damaged and consequently die. Due to the lack of information on this, timescales for this process are not available. Moderately strong water flows caused by tidal movements within this biotope could remove from the shore within a few tidal cycles. Germlings are likely to be smothered and killed regardless of the state of the tide and are inherently most susceptible to this pressure. 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 microenvironment (Devinny & Volse, 1978, Eriksson & Johansson, 2003).

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen , (1987) exposed thallus discs (113 mm^2) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). Although *Ulva* sp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggests that resistance to this pressure may be lower.

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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	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

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 *Fucus ceranoides* is found in the middle its natural range in the British Isles an increase or decrease in the level of diffuse irradiation will not cause a negative impact on the species or the biotope.

A number of experiments have demonstrated that *Ulva lactuca*, has high tolerance for shading and can survive periods of darkness. Vermaat & Sand-Jensen (1987) found that *Ulva lactuca*, collected from Roskilde Fjord in Denmark in late autumn had extremely high shade tolerances.

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.

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-native species in the British Isles that invade reduced salinity intertidal rocky shores where this biotopes is found. The Australasian barnacle *Austrominius* (syn. *Elminius) modestus* was introduced to British waters on ships during the second world war. *Austrominius modestus* is now described as a species which naturally occurs within this biotope. 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).

Sensitivity assessment. Fucoid species have been negatively affected by both the direct and indirect consequences of INIS being present. However, no evidence can be found on the impacts of INIS on *Fucus ceranoides* within this biotope. Therefore, 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. No evidence is available on the microbes that are associated with the characterizing species *Fucus ceranoides* or *Ulva* sp. Barnacles are considered subject to persistent, low levels of infection by pathogens and parasites. But little specific information on the effects they have on their hosts is available.

Sensitivity assessment. Due to the lack of information on the effect of microbial pathogens on the species found within this biotope an assessment of 'No evidence' has been given.

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

There is no evidence of target harvesting of the characterizing species, *Fucus ceranoides.* Therefore, this pressure is assessed as ‘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 *Fucus ceranoides* is a dominant species 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. Incidental 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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