Fucus distichus and *Fucus spiralis f. nana* on extremely exposed upper shore rock

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

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View down shore showing upper shore bedrock with *Fucus distichus* and green algae.
Photographer: Sue Scott
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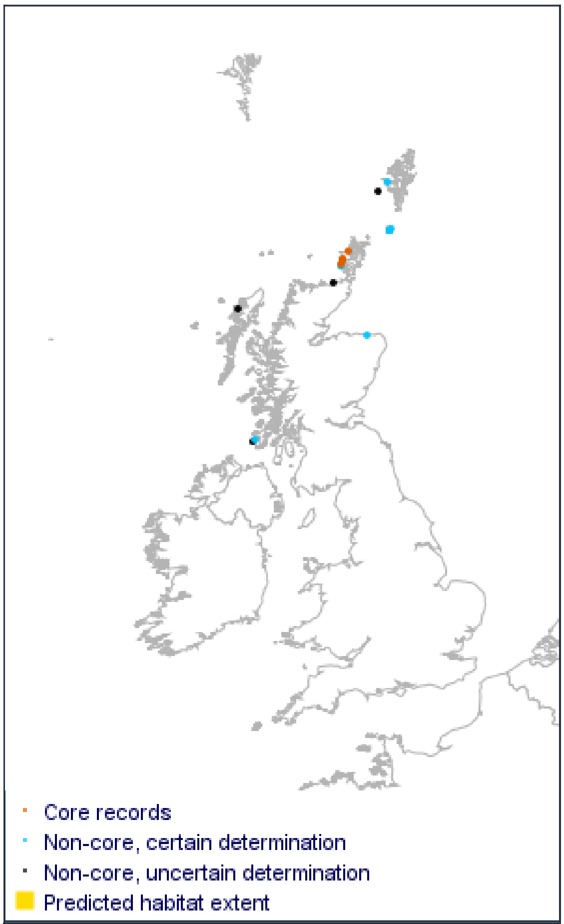

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Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Frances Perry & Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.121	*Fucus distichus* and *Fucus spiralis* f. *nana* on extremely exposed upper eulittoral rock
JNCC 2015	LR.HLR.FR.Fdis	*Fucus distichus* and *Fucus spiralis f. nana* on extremely exposed upper shore rock
JNCC 2004	LR.HLR.FR.Fdis	*Fucus distichus* and *Fucus spiralis* f. nana on extremely exposed upper shore rock
1997 Biotope	LR.ELR.FR.Fdis	*Fucus distichus* subsp. anceps and *Fucus spiralis f. nana* on extremely exposed upper eulittoral rock

Description

Extremely exposed, gently or steeply sloping upper shore bedrock that supports a mixture of the wracks *Fucus distichus* and *Fucus spiralis* f. *nana*; the latter often at the top of the zone. On some sites, *Fucus distichus* dominates and *Fucus spiralis* are not present. Other seaweeds normally found on exposed coasts are common in this biotope. These include ephemeral species such as the foliose red *Porphyra umbilicalis* and the green *Ulva* spp. The winkles *Melarhaphe neritoides* and *Littorina saxatilis* can be found grazing on the bedrock or on the fucoids, while red crusts of *Hildenbrandia rubra* and the mussel *Mytilus edulis* are restricted to moist cracks and crevices. A sparse covering of the black lichens *Verrucaria maura* and *Verrucaria mucosa* can be found in the upper part of this biotope competing for space with barnacle *Semibalanus balanoides* and the limpet *Patella vulgata*.

This mixed band of *Fucus distichus* and *Fucus spiralis* f. *nana* is generally found between the *Verrucaria maura* and *Porphyra* spp. zone (Ver.Ver or Ver.B) above, and the *Mytilus edulis* and barnacle zone below (MytB). It may also occur above a red algal zone consisting of *Mastocarpus stellatus* as recorded on Barra. (Information from Connor *et al.*, 2004).

Depth range

Upper shore, Mid shore

Additional information

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Listed By

- none -

Further information sources

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Habitat review

Ecology

Ecological and functional relationships

- In general exposed conditions favour the growth of barnacles, limpets and mussels rather than fucoid algae. However, the ELR.Fdis biotope includes seaweeds that are able to tolerate the extreme conditions of wave exposed rocky shores, primarily the physical stresses caused by wave action. The strong holdfast and short tufted structure of *Fucus distichus* and *Fucus spiralis* f. *nana* allow these fucoids to survive on extremely exposed shores in the north and north-west. Other seaweeds able to tolerate the wave-wash are the red encrusting algae *Hildenbrandia rubra* and seasonally occurring *Porphyra* spp.
- In Britain and Ireland, *Fucus distichus* has only been recorded attached to bedrock in the mid to upper eulittoral zone on exposed rocky shores in northern Scotland and Ireland. It is thought to be prevented from growing further south due to its poor tolerance of desiccation and inability to compete with plants growing further down the shore. However, on the east coast of North America, *Fucus distichus* is only found in rock pools and is incapable of growing on emergent rock surfaces in the mid to upper eulittoral. The isolated and dispersed occurrence of *Fucus distichus* together with a greater abundance on more northerly shores of the North Atlantic suggest that it may be a relic form surviving only in habitats which are unsuitable for the main fucoids found at these latitudes (Lewis, 1964). A critical factor in the distribution of *Fucus distichus* is probably day length. Short day lengths stimulate the onset of receptacle formation (Bird & McLachlan, 1976).
- Grazing on rocky shores can exert significant controlling influences on the algal vegetation, particularly by patellid limpets and littorinid snails which are usually the most prominent grazers. There may also be effects caused by 'mesograzers' - amphipods such as *Hyale prevostii* and isopods, which are much smaller but can occur in high densities.
- The surf-swept conditions under which both *Fucus distichus* and *Fucus spiralis* f. *nana* occur are not always conducive to the formation of well-defined zones. Scattered plants or thick ankle-deep carpets can often lie somewhat randomly placed (Lewis, 1964).
- The presence of a fucoid canopy inhibits the settlement of barnacles 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. The number of limpets increases with maturing fucoid clumps.

Seasonal and longer term change

Rocky shore communities are often highly variable in time, due to the combined influences of physical disturbance, competition, grazing, predation and variation in recruitment. However, the communities on wave exposed shores tend to be less variable than on moderately exposed shores and are therefore more stable. The wave exposed conditions in this biotope seems to favour the development of a relatively stable covering of wave tolerant fucoids plus a patchy covering of barnacles and limpets. However, seasonal changes are apparent on rocky shores with seasonal variation in growth and recruitment. For example, *Fucus distichus* plants lose fronds in the autumn after reproducing and are then removed from the rock by wave action during their third winter.

Habitat structure and complexity

The ELR.Fdis biotope provides a variety of habitats and refugia for other species. Macroalgae increases the structural complexity of the habitat providing a variety of resources that are not available on bare rock. Algal fronds provide space for attachment of encrusting or sessile epifauna and epiphytic algae and give shelter from wave action, desiccation and heat for invertebrates. Empty barnacle shells can shelter small littorinids such as *Littorina neglecta* and *Littorina saxatilis*. If present mussels can increase habitat complexity and species diversity because the gaps between interconnected mussels form numerous interstices for a variety of organisms. The barnacles may be covered by *Porphyra* sp. on the upper shore although few other species can attach to them.

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 taken up 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 such as in the gaps often created by storms. 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). Both the demographic structure of populations and the composition of assemblages may be profoundly affected by variation in recruitment rates.

- Receptacles of *Fucus distichus* are initiated in December, they become ripe in April and gametes are released from April to August. The species produces gametes of both sexes within each conceptacle. When released, ova can survive and disperse for several days. Antherozoids can only live for several hours. Self-fertilization is thought to be high in the species and once a zygote is formed it can only be dispersed over limited distances (Rice *et al*., 1985).
- *Fucus spiralis* is also hermaphroditic. Receptacles are initiated during late January to February, gametes discharged during July and August, and the receptacles shed by November, although exact timing of reproduction depends on location and the form of the plant.
- Among sessile organisms, patterns fixed at settlement, though potentially altered by post settlement mortality, obviously cannot be influenced by dispersal of juveniles or adults. Some of the species that may be found living in the biotope, such as amphipods, do not have pelagic larvae, but instead have direct development of larvae producing their offspring as 'miniature adults'.

Time for community to reach maturity

The time for the biotope to reach maturity should be relatively rapid because recruitment of key species is good. For example, *Fucus distichus* and *Fucus spiralis* have been observed to readily recruit to cleared areas (Ang, 1991) and have fast growth rates, so recovery rates are expected to be high. *Fucus distichus* has a lifespan of about 3 years. Colonization by other species found in the biotope, such as *Littorina neglecta* and *Melarhaphe neritoides*, is also likely to be quite rapid. Therefore, it seems likely that the biotope should reach maturity within a few years.

Additional information

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Preferences & Distribution

Habitat preferences

Depth Range	Upper shore, Mid shore
Water clarity preferences	
Limiting Nutrients	Nitrogen (nitrates), Phosphorus (phosphates)
Salinity preferences	Full (30-40 psu)
Physiographic preferences	Open coast
Biological zone preferences	Lower littoral fringe, Mid eulittoral, Upper eulittoral
Substratum/habitat preferences	Bedrock
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 exposed
Other preferences	

Additional Information

Species composition

Species found especially in this biotope

- *None*

Rare or scarce species associated with this biotope

-

Additional information

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The biotope is a fucoid dominated community characterized by *Fucus distichus* and *Fucus spiralis* forma *nana*. On some sites *Fucus distichus* dominates and *Fucus spiralis* is not present. Other seaweeds tolerant of exposed conditions can occur in this biotope. Species include *Porphyra umbilicalis* and *Ulva* spp. Gastropod grazers found within this biotope include *Melarhaphe neritoides* and *Littorina saxatilis. Mytilus edulis* is present but is restricted to crevices where the environmental conditions are less severe. *Semibalanus balanoides* and the limpet *Patella vulgata* compete for space with black lichens on the upper section of the shore. This biotope is rare and restricted to the far north and west coasts of Scotland and Ireland.

It is important to note that there is some discussion as to the different forms and subspecies of both *Fucus distichus* and *Fucus spiralis.* The *Fucus spiralis* f. *nana* given in the JNCC biotope description is not recorded on the World Register of Marine Species (WoRMS). There is a similar form of *Fucus spiralis* named *Fucus spiralis* f. *nanus* recorded from the British Isles found within similar environmental conditions as described within this biotope (Scott *et al.*, 2001). It is also the only form of *Fucus spiralis* referenced to in literature and on WoRMS with a similar name to *Fucus distichus* f. *nana*. However *Fucus spiralis* f. *nanus* is not accepted on WoRMS as a form of *Fucus spiralis.* The distinction between *Fucus spiralis* and *Fucus spiralis* f. *nanus* are as follows. Niemeck & Mathieson (1976) noted that specimens of *Fucus spiralis* further up the shore tended to decrease in length and weight. Scott *et al.* (2001) later noted that *Fucus spiralis* f. *nanus* had a relatively small number of short, thin blades that branched fewer times than *Fucus spiralis* plants. Observations by Scott *et al.* (2001) also found *Fucus spiralis* f. *nanus* higher on the shore than *Fucus spiralis.* However, the two morphotypes can overlap on the shore. Scott *et al.* (2001) suggested that forms of *Fucus spiralis* exist within a mosaic of stable phenotypes representing populations specifically adapted to the local environment. For this assessment, it has been assumed that *Fucus spiralis* f. *nanus* is *Fucus spiralis* f. *nana* and information for *Fucus spiralis* f. *nanus* is included within the pressure assessments.

Although the JNCC biotope description only specifies *Fucus distichus*, Bunker *et al.*, (2012) recorded two subspecies of *Fucus distichus* in the British Isles. These two subspecies are *Fucus distichus* spp. *anceps* and *Fucus distichus* spp. *edentatus.* These two subspecies show different morphologies and grow on shores with different exposure levels (Bunker *et al.*, 2012). The *Fucus distichus* subspecies that is most likely to be found within this biotope is *Fucus distichus* f. *anceps.* The fronds of this subspecies are usually between 6-10 cm and it is only found on exposed intertidal rocky shores (Bunker *et al.*, 2012). The other subspecies, *Fucus distichus* f. *edentatus* has longer fronds, reaching 20-45 cm in length and is restricted to sheltered locations (Bunker *et al.*, 2012). Sideman & Mathieson (1983a) recorded that a dwarf form of *Fucus distichus* found on an exposed shore in Maine had both an earlier maturation time and a single reproductive period per annum, in contrast to *Fucus distichus* f. *edentatus* for which two periods of reproductive activity and later maturation were recorded.

Other species are present in the biotope, however, the fucoids are important in determining the sensitivity of the biotope. Therefore this review focuses on *Fucus distichus* and *Fucus spiralis.* Although the different forms and subspecies of *Fucus distichus* and *Fucus spiralis* are described and appear to have some differences in morphology and ontogeny, none of the forms or subspecies are accepted on WoRMS. This assessment uses information that refers to *Fucus distichus* and the dwarf forms that occur only of exposed shores, and for *Fucus spiralis* f. *nanus* and *Fucus spiralis.*

Resilience and recovery rates of habitat

Fucus spiralis is a relatively short-lived perennial alga. A lifespan of up to five years (S. H. Brawley, personal observation) was recorded, but other authors observed an average lifespan of two years (Niemeck & Mathieson, 1976). *Fucus spiralis* growth rates peak in the summer of 1.9 – 2.8 cm/month, and an average of 1.2 cm/month over the entire year (Niemeck & Mathieson, 1976). Variations in growth rate are found between the north east and north west Atlantic (Niemeck & Mathieson, 1976; Subrahmanyan, 1961; Hariot, 1909). A ten month reproductive cycle has been recorded for *Fucus spiralis* populations in both New Hampshire and the Isle of Man (Niemeck & Mathieson, 1976; Subrahmanyan, 1961). The cycle starts in late January, when the receptacles appear, and concludes in the late summer, July or August, when the gametes are released (Niemeck & Mathieson, 1976). Both Niemeck & Mathieson (1976) and Subrahmanyan (1961) recorded that plants had to reach approx. 10 cm before forming receptacles, which was found to be at the end of the second year's growth. This species is a hermaphrodite, a reproductive strategy that is also mirrored by *Fucus distichus.*

Fucus distichus has a similar life expectancy to that of *Fucus spiralis*, with individual plants living for an average of three years. An experiment investigation of *Fucus distichus* spp. *edentatus* and *Fucus distichus* spp. *evanescens* on the north western coast of the Atlantic found that increases in frond length varied between 3.5 and 3.7 cm/28 days respectively (Sideman & Mathieson, 1983b). Ang (1991) investigated a *Fucus distichus* subspecies and found that in the summer absolute growth rates were 0.24 – 1.17 cm/month, and -0.5 – 0.4 cm/month over the winter. *Fucus distichus* is a hermaphrodite and each plant has the ability to self fertilize. Receptacles of *Fucus distichus* are initiated in December, become ripe in April and gametes are released from April to August (Powell, 1957b). When released, ova can survive and disperse for several days; antherozoids can only live for several hours (Rice *et al.*, 1985). Self-fertilization is thought to be high in the species and once a zygote is formed it can only be dispersed over limited distances (Rice *et al.*, 1985). In the UK, *Fucus distichus* is found at near its southern limit. One factor that is thought to be critical to the distribution of this species is day length. Bird & McLachlan (1976) found that short day lengths stimulate the formation of receptacles in *Fucus distichus* populations in Canada. Only very young *Fucus distichus* are able to regenerate from a damaged stump or holdfast (Ang, 1991).

No records of significant reductions in the cover of either *Fucus distichus* or *Fucus spiralis* were available. Little *et al.* (1992) recorded a decline in the cover of *Fucus spiralis* in Lough Hyne between 1955-1990/91 but gave no indication of what may have caused the decline. No further information can be found on trends in *Fucus spiralis* cover and no information is available for *Fucus distichus. Fucus distichus* may be less tolerant of pressure changes as it is found at the southern limit of its distribution in the UK, and is only recorded in Scotland and Ireland. Hawkins & Southward (1992) found that fucoids had returned in dense stands 2 - 5 years after the use of toxic dispersants to clean up oil from the *Torrey Canyon* oil spill. These dense stands were even found on shores where the use of toxic dispersants was so thorough that re-colonization started from bare rock. However, the time taken for rocky shore ecosystems to reach a state of equilibrium after the disturbance event was between 10 - 15 years (Hawkins & Southward, 1992). Ang & De Wreede (1992) cleared 14 plots 50 x 50cm in the size of all organisms in September 1985, *Fucus distichus* recruits were recorded from February 1986. The area surrounding the cleared plots contained a high density of *Fucus distichus.*

Intertidal rocky shores usually have high levels of water flow and mixing (Hawkins & Southward, 1992). The exposed situation of this biotope means that the levels of water mixing are even greater. As broadcast spawners with external fertilization (Engel *et al.*, 2005) the reproductive capacity of both of these fucoids must allow for these conditions. The hermaphroditic reproductive ability of both *Fucus distichus* and *Fucus spiralis* may not appear to be advantageous bearing in mind all fertilization is external. However, research has shown that this reproductive method does allow for high fertilization rates (Serrao *et al.*, 1996a; Berndt *et al.*, 2002). The dispersal distance of fucoid eggs is generally within ca 0.5 m (Berndt *et al.*, 2002). This can be attributed to the negative buoyancy of eggs, the negative phototaxis of sperm (Brawley *et al.*, 1999), and the release of gametes during calm periods of weather when water movement is low.

Resilience assessment. Both *Fucus distichus* and *Fucus spiralis* attach to the substratum by a holdfast and are not able to relocate in response to an increase in a pressure. Therefore the resilience of a population to an increase in pressure which increases damage or mortality will depend on its ability to repopulate the environment. If *Fucus distichus* or *Fucus spiralis* remain in small quantities after a disturbance event it is likely that recovery to a previous ecosystem function will occur within 2 –10 years. The high fertilization rates, as both species are hermaphroditic, could allow recruitment to take place within one season, as reported by Ang & De Wreede (1992) and Hartnoll & Hawkins (1985). If the impacts of a pressure were so severe that re-colonization had to begin from scratch then it could take between 10 - 15 years for the ecosystem to return to a functional state similar to that prior to the disturbance. This estimate is taken from the evidence provided by Hawkins & Southward (1992) on the recovery of shores after the *Torrey Canyon* oil spill. A resilience of 'Medium' has been suggested, as it will take longer than two years for the biotope to return to a functional state equivalent to that prior to the disturbance event.

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

The southern limit of *Fucus distichus* distribution in the North East Atlantic is found in Scotland (Rice & Chapman, 1985). If there was to be an increase in the pressure at this benchmark then it is highly likely that there would be a loss of *Fucus distichus* from the biotope.

Fucus spiralis can tolerate temperatures from -0.5 to 28°C. The species is well within its temperature range in the UK. Decreases in temperature are unlikely to have any effect because the species extends into northern Norway where water temperatures are cooler. Increase in temperature may be beneficial because the optimum temperature for growth of the species is 15°C (Lüning, 1990). However, *Fucus spiralis* was reported to suffer some damage during the unusually hot summer of 1983 when temperatures were on average 8.3°C higher than normal

(Hartnoll & Hawkins, 1985).

Sensitivity assessment. *Fucus spiralis* is found in the middle of its natural temperature range in the British Isles. Therefore, it will probably not be affected by an increase in 5°C for one month or an increase of 2°C for one year. However, *Fucus distichus* will not tolerate an increase in temperature as it is on the edge of its range in the northern parts of the British Isles. Considering that a loss of *Fucus distichus* from the biotope will lead to a loss of the biotope the resistance has been scored as ‘Low’. Resilience is assessed as ‘Medium’. The biotope has ‘Medium’ to this pressure at the pressure benchmark.

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

The northern range of *Fucus distichus* extends up to Norway in the North East Atlantic (Rice & Chapman, 1985). This species is tolerant of freezing (Pearson & Davison, 1994). A change in this pressure at this benchmark is unlikely to have a detrimental effect on *Fucus distichus.*

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Sensitivity assessment. Due to the natural tolerances of both *Fucus distichus* and *Fucus spiralis* it is highly unlikely that a decrease in 5°C for one month or a decrease of 2°C for one year would have a negative impact on the biotope. Resistance is assessed as ‘High’ as is resilience because there is no impact to recover from. The biotope is assessed as ‘Not Sensitive’ to this pressure at the pressure benchmark.

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

The biotope occurs in areas of full salinity although it will be subject to variability due to rainfall. There are no reports of the biotope occurring in hypersaline areas such as rockpools, where evaporation in the summer causes salinity to increase. Therefore, any increase in salinity is likely to impact the functioning of the community.

Fucus spiralis populations in New Hampshire have been reported to survive between 2 – 32 psu (Niemeck & Mathieson, 1976). This species has also been shown to experimentally tolerate salinities of 3 to 34 psu. Both experimental testing and natural range of this species suggest that the species would not be tolerant to long-term increases in salinities. There is no evidence concerning the ability of *Fucus spiralis* gametes to tolerate increases in salinity. However, Niemeck & Mathieson (1976) noted that the initiation and maturation of receptacles in *Fucus spiralis* populations in New Hampshire occurred during periods of high freshwater runoff in the spring. This could possibly indicate that decreases in salinity could be an environmental cue for gamete release. No evidence testing this theory is available.

Fucus distichus appears more tolerant of increases in salinity. The effects of salinity on the photosynthetic function in *Fucus distichus* were investigated by Karsten (2007). The experiment found that salinities ranging from 5 – 60 psu had no detrimental effect (Karsten, 2007). This study only investigated the impact of changes in salinity on the photosynthetic capacity of the macroalgae and did not take other factors of *Fucus distichus* ontogeny into consideration. For a number of fucoids both fertilization and recruitment are limited by the osmotic tolerance of their gametes (Serrao *et al.*, 1996a; Malm *et al.*, 2001). Pearson & Brawley (1996) noted that fewer gametes were released when large salinity gradients were present. No further evidence was found to indicate how any changes in salinity affect the reproductive success of *Fucus distichus.*

Sensitivity assessment. This biotope occurs in fully saline conditions, therefore, an increase in salinity is unlikely. Adult *Fucus distichus* are able to photosynthesise in hypersaline conditions, however, the osmotic tolerance of their gametes is unknown. There is no evidence to suggest that *Fucus spiralis* can tolerate hypersaline conditions. *Fucus distichus* appears to have some tolerance to increases in salinity. In some locations, it is reported that this biotope is found without the presence of *Fucus spiralis.* A case where this biotope was present without *Fucus spiralis*, an increase in salinity may not have as much of an impact on an example of a biotope with *Fucus spiralis* present. Where both *Fucus distichus* and *Fucus spiralis* are present, resistance and resilience are assessed as 'Medium', to represent the possible loss of *Fucus spiralis*. Therefore, sensitivity is assessed as 'Medium' at the pressure benchmark.

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

The biotope occurs in areas of full salinity although it will be subject to variability due to rainfall. Therefore there is a requirement for the species within this biotope to be tolerant of short-term decreases in salinity.

Fucus spiralis populations in New Hampshire have been reported to survive between 2 – 32 psu (Niemeck & Mathieson, 1976). This species has also been shown to experimentally tolerate salinities of 3 to 34 psu. Both experimental testing and natural range of this species suggest that the species could be tolerant to long-term decreases in salinities. There is no evidence concerning the ability of *Fucus spiralis* gametes to tolerate decreases in salinity. However, Niemeck & Mathieson (1976) noted that the initiation and maturation of receptacles in *Fucus spiralis* populations in New Hampshire occurred during periods of high freshwater runoff in the spring. This could possibly indicate that decreases in salinity could be an environmental cue for gamete release. No evidence testing this theory is available.

Fucus distichus also appears tolerant of decreases in salinity. The effects of salinity on the photosynthetic function in *Fucus distichus* were investigated by Karsten (2007). The experiment found that salinities ranging from 5 – 60 psu had no detrimental effect (Karsten, 2007). This study only investigated the impact of changes in salinity on the photosynthetic capacity of the macroalgae and did not take other factors of *Fucus distichus* ontogeny into consideration. For a number of fucoids both fertilization and recruitment are limited by the osmotic tolerance of their gametes (Serrao *et al.*, 1996a; Malm *et al.*, 2001). Pearson & Brawley (1996) noted that fewer gametes were released when large salinity gradients were present. No further evidence was found to indicate how any changes in salinity affect the reproductive success of *Fucus distichus.*

Sensitivity assessment. Both *Fucus distichus* and *Fucus spiralis* appear to have some tolerance to decreases in salinity but the biotope is characteristic of full salinity conditions. A change in salinity from ‘full’ to’ reduced’ may result in the loss of the biotope in the long-term due to competition from brackish water fucoids, e.g. *Fucus ceranoides* but the biotope may survive reduced conditions for a year (the benchmark). Resistance is assessed as ‘Medium’ to represent a loss in species richness within the biotope, and resilience is ranked as ‘High’. This gives the biotope an overall sensitivity assessment of ‘Low’ to this pressure at the pressure benchmark.

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

Water motion determines marine macroalgal production and can influence physiology and community structure (Hurd, 2000). Higher water flow rates increase mechanical stress on macroalgae by increasing drag. Once drag exceeds a certain strength algae will be removed from the substrate. Once removed, the attachment cannot be reformed causing the death of the algae.

Adult fucoids are highly flexible and are able to re-orientate their position in the water column to become more streamlined. This reduces the relative velocity between algae and the surrounding water, thereby reducing drag and lift (Denny *et al*., 1998). Jonsson *et al*. (2006) found that flow speed of 7-8 m/s completely dislodged *Fucus spiralis* individuals larger than 10 cm. Smaller individuals are likely to be able to tolerate increased water flow as they experience less drag. Increased water flow also causes greater levels of scour through increased sediment suspension and movement (Devinny & Volse, 1978). Small life stages such as newly settled recruits are less tolerant to scour than adults and are more easily removed from the substratum. Consequently, an increase in scour can reduce successful recruitment to a shore (Devinny & Volse, 1978). Changes in water motion can thus strongly influence local distribution patterns of *Fucus* spp. (Ladah *et al*., 2008)

Propagule dispersal, fertilization, settlement, and recruitment are also influenced by water movement (Pearson & Brawley, 1996). *Fucus distichus* (also a hermaphrodite species) on an exposed intertidal rocky shore can achieve fertilization rates between 78 – 100% by releasing their gametes during periods of very low water movement (Pearson & Brawley, 1996). An increase of water flow may decrease the amount of time during which flow rates are low enough for successful reproductive and recruitment processes.

A reduction in water flow can cause a thicker boundary layer resulting in lower absorption of nutrients and CO$_2$ by the macroalgae. Slower water movement can also cause oxygen deficiency directly impacting the fitness of algae (Olsenz, 2011). However, due to the occurrence of this biotope within areas with moderate tidal flow rates (Connor *et al*., 2004; littoral rock matrix), a change in of the flow rate at the benchmark for this pressure is unlikely to have a negative impact on the biotope.

Sensitivity assessment. The LR.HLR.FR.Fdis biotope is found in areas with moderate water flow but extreme wave exposure so that wave meditated flow if probably the most important source of water flow. Therefore, a 0.1-0.2 m/s change in water flow is probably not significant. Resistance and resilience are both assessed as ‘High’ and the biotope is probably ‘Not sensitive’ at the benchmark level.

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

This biotope is found in the eulittoral zone and is subjected to cyclical immersion and emersion caused by tides. *Fucus spiralis* can tolerate up to 90% loss of tissue water (Schagerl & Mostl, 2011). Although the southern extent of *Fucus distichus* is thought to be limited by desiccation, as long as temperatures do not get too high, it can remain exposed in air for long periods of time. If emersion leads to a level of water loss above which the alga is tolerant, the algae will suffer from irreversible desiccation and nutrient stress damage.

During the initial stages of drying, when the alga are exposed to air, photosynthetic rates increase due to the higher diffusion rate of CO_2 in air relative to water (Johnson *et al*., 1974). Rates of photosynthesis in *Fucus distichus* can be 1.6 – 6.6 times greater out of water, than in water at the same temperature and with the same light levels (Johnson *et al*., 1974). However, the distribution of *Fucus distichus* in the UK is restricted to the north, due to its intolerance of high levels of desiccation.

Fucus spiralis can also photosynthesize better in air than in water, as long as desiccation has not exceeded tolerated levels of water reduction (Madsen & Maberly, 1990). However, this peak in photosynthesis is usually followed by a gradual decline in the rate of photosynthesis as the surface of the alga dries, thereby preventing further dissolution and uptake of CO_2 (Beer & Kautsky, 1992). Photosynthesis eventually ceases at a critical state of dehydration when the low water content of the thallus disrupts the functioning of the photosynthetic apparatus (Quadir *et al*., 1979). An increase in the levels of immersion would mean that both of these species would eventually be out-competed by faster growing macroalgae species found lower down on the shore (Chapman, 1990; Lubchenco, 1980). It could be hypothesised that the less efficient photosynthesizing of these two species in water is the reason that other plants can grow faster, and out-compete them. However, an increase in emersion may shift the upper shore zone up the shore, even if this is the case it may take some time for the biotope to resume ecological function.

Changes in immersion and emersion times will also affect the ability of plants to uptake nutrients. Hurd & Dring (1991) investigated the ability of macroalgae to uptake phosphate after desiccation. Results showed that macroalgae found higher on the shore were able to recover from desiccation and were able to resume uptake of phosphates faster (Hurd & Dring, 1991). They also hypothesised that patterns of zonation on intertidal rocky shores could be partially driven by the ranging sensitivities of nutrient uptake mechanisms in different species (Hurd & Dring, 1991).

Early life history stages are more susceptible to ultraviolet radiation compared to adults (Henry & Van Alstyne, 2004; Roleda *et al*., 2007). Germlings are however protected from desiccation by the canopy of adults. A study by Brawley & Jonhnson (1991) showed that germling survival under adult canopy was close to 100% whereas survival on the adjacent bare rock was close to 0% during exposure to aerial conditions. *Fucus* canopies are also likely to protect other underlying species. Mortalities of other species are likely to occur if the canopy is removed.

A change in the level of emergence on the shore will affect *Fucus distichus* and *Fucus spiralis*, as well as other species within the biotope. Changes in the numbers of important species are likely to have profound effects on community structure and may result in loss of the biotope at the extremes of its range. For example, the upper limit of the biotope may lose fucoid cover and change to an alternative biotope dominated by barnacles and limpets or lichens. However, the more widespread form of *Fucus spiralis* can tolerate an emersion period of 1-2 days so an increase in time spent in air of 1 hour in per day may limit growth and fecundity rather than survival. Although care is needed in extrapolating information on the physiological tolerances of the widespread form of *Fucus spiralis* to *Fucus spiralis* f. *nana* it seems likely that only those species at the extremes of their physiological limits would die. Limpets are able to move down the shore although the loss of a home scar can increase the species vulnerability to predation (Garrity & Levings, 1983). Thus, the biotope is likely to be lost only at the very upper limit of its range. A change in the level of emergence on the shore may also affect the lower distribution limit of all the key species as competition increases lower down the shore. Growth, condition and fecundity are likely to return within several months if pre-impact emersion levels return.

Sensitivity assessment. The consequences of an increase in emersion are severe desiccation due to increased time in air. When these factors are combined with high temperatures and light can cause mortalities (Pearson *et al*., 2009). This will lead to a decrease in the band of this biotope at the top of a rocky shore. It would also lead to an increase in the level of emersion of other algae further down the shore. Although there will be a period of mortality, in time it may result in a readjustment of biotopes further down the shore. An increase in immersion is likely to result in an upward movement of biotopes on the shore. Resistance is assessed as 'Medium' and resilience as 'Medium' giving an overall sensitivity assessment of 'Medium'.

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

An increase in wave exposure generally leads to a decrease in macroalgae abundance and size (Blanchette, 1997; Lewis, 1961; Stephenson & Stephenson, 1972; Hawkins *et al*., 1992; Jonsson *et al*., 2006). However, this biotope is found in areas of extreme wave exposure (Connor *et al*., 2004) and any further increase in wave exposure is unlikely.

This biotope is extremely wave exposed, therefore the characterizing species *Fucus distichus* and *Fucus spiralis* are highly resistant of wave exposure is required. However, a shift to more sheltered conditions would allow other faster growing fucoid species to inhabit the shore. These species would out-compete *Fucus distichus* and *Fucus spiralis*, leading them to be lost from the shore. Barnacle and limpet abundance may also increase and lead to the development of a different biotope, e.g. *Fucus serratus* and barnacle dominated biotopes. Therefore, a decrease in wave exposure is like to result in the loss of the biotope.

Sensitivity assessment. However, a change of 3-5% in significant wave height is unlikely to be significant in the exposed conditions typical of this biotope and the biotope is 'Not sensitive' (resistance and resilience are 'High') at the benchmark level.

Chemical Pressures

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

Adult fucoid plants appear to be fairly tolerant of heavy metal pollution although earlier life stages may be more sensitive (Holt *et al*., 1997). Barnacles are able to concentrate heavy metals in their tissues and *Patella vulgata* is found living in conditions of fairly high metal contamination in the Fal Estuary in Cornwall (Bryan & Gibbs, 1983). Recovery from sub-lethal effects will be very high as metabolism and growth return to normal.

Nevertheless, this pressure is **Not assessed**.

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

The loss of key herbivores, such as limpets and littorinids, and the subsequent prolific growth of ephemeral algal mats appears to be a fairly consistent feature of coastal oil spills (Hawkins & Southward, 1992). Species richness, diversity and evenness were all much lower in fucoid-barnacle communities at sites close to the *Braer* oil spill (Newey & Seed, 1995). In the absence of tarry masses of oil which cause physical smothering of sessile animals and mechanical damage to algae, adult fucoids and barnacles occupying primary space in the community are relatively resistant to damage from chemical properties of the oil itself, although some damage will inevitably occur. The most serious effects tend to occur among juvenile and newly settling recruits to the community. However, this biotope is subject to very strong wave action and therefore, oil is likely to be rapidly removed and not cause smothering effects.

Nevertheless, this pressure is **Not assessed**.

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

There is no information available on the effects of chemicals on the biotope as a whole. However, there is some information on the effects of several chemicals on the species that make up the biotope. Fucoids in general, for example, are reported to exhibit high intolerance to chlorate and pulp mill effluents containing chlorate (Kautsky, 1992). *Patella vulgata* is extremely intolerant of aromatic solvent based dispersants such as those used in the *Torrey Canyon* oil spill clean-up (Smith, 1968). However, on rocky coasts of Amlwch in areas close to acidified halogenated effluent from a bromine plant the shore consisted almost entirely of bare rock but there was a fucoid-barnacle mosaic nearby (Hoare & Hiscock, 1974). Therefore, effects depend on the chemical under consideration and there is obviously tolerance to some chemicals.

Neverthelthis pressure is **Not assessed**.

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 was found.

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

This pressure is **Not assessed**.

De-oxygenation	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Cole *et al*. (1999) suggest possible adverse effects on marine species below 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. Sustained or repeated episodes of reduced dissolved oxygen have the potential to severely degrade an ecosystem (Cole *et al.*, 1999).

Josefson & Widbom (1988) investigated the response of benthic macro and meiofauna to reduced dissolved oxygen levels in the bottom waters of a fjord. At dissolved oxygen concentrations of 0.21 mg/l, the macrofaunal community was eradicated and was not fully re-established 18 months after the hypoxic event. Meiofauna seemed, however, unaffected by de-oxygenation. Kinne (1970) reported that reduced oxygen concentrations inhibit both algal photosynthesis and respiration. However, no specific information about the effects of deoxygenation on the characteristic species was found.

Sensitivity assessment. The biotope in question occurs in the upper eulittoral and consequently, a high proportion of time will be spent in air where oxygen is not limited so the metabolic processes of photosynthesis and respiration can take place. The highly exposed locations where this biotope is found means that there will always be high levels of water mixing created by tidal streams, currents and waves. All of these factors are likely to maintain high oxygen levels. Therefore, the biotope is probably ‘Not sensitive' (resistance and resilience are 'High') at the benchmark level.

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

The nutrient enrichment and the consequent changes in ecosystem functions can lead to eutrophication (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 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 these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Littler & Murray, 1975; Abou-Aisha *et al.*, 1995; Archambault *et al.*, 2001; Arévalo *et al.*, 2007; Diez *et al.*, 2003).

Major declines of *Fucus vesiculosus* have been reported from all over the Baltic Sea. These declines have been associated to eutrophication from nutrient enrichment (Kautsky *et al.*, 1986). 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). High nutrient levels may directly inhibit spore settlement and hinder the initial development of *Fucus vesiculosus* (Bergström *et al.*, 2003).

Changes in community composition on intertidal rocky shores can happen rapidly, and levels of wave exposure are not a controlling factor for the speed of these changes (Kraufvelin, 2007). However, well established and healthy communities on intertidal rocky shores can survive extended periods of time (Bokn *et al.*, 2002, 2003, Karez *et al.*,2004; Kraufvelin, 2007; Kraufvelin *et al.*, 2006). There is little evidence available on the impacts of nutrient enrichment on the characterizing species of this biotope.

Nevertheless, the biotope is considered 'Not Sensitive' at the benchmark level, which assumes compliance with good status as defined by the WFD.

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

The organic enrichment of a marine environment can lead to eutrophication (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 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 these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Littler & Murray, 1975; Abou-Aisha *et al.*, 1995; Archambault *et al.*, 2001; Arévalo *et al.*, 2007; Diez *et al.*, 2003).

Although the effects of increased organic enrichment can have negative impacts on intertidal rocky shores, these impacts can be very localised. Husa *et al.* (2014) found that the macroalgae communities beyond the immediate proximity of fish farms in Hardangerfjord, Norway, seemed to be little affected by the deposition of organic matter from the salmon farming industry. Holt *et al.* (1997) reported fucoids growing apparently healthily to within 20 m of an outfall discharging untreated sewage in the Isle of Man. There is little evidence available on the impacts of organic enrichment on the characterizing species of this biotope. *Fucus spiralis* is reported to be more common than other fucoids in the sewage polluted inner part of the Oslofjord, Norway (Fletcher, 1996). No direct reference to *Fucus distichus* was found. Organic sedimentation may also cover the available substratum and thereby reduce the settlement of Fucoids (Eriksson & Johansson, 2003) (see 'sedimentation' pressure).

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. The effect of sewage discharge in the extremely exposed environment required by this biotope is likely to be low because water movements should limit the build up of particulates and prevent eutrophication. At the level of the benchmark, some mortality of *Fucus* may be likely resulting in 'Medium' resistance. Resilience is assessed as 'High'. This gives an overall sensitivity score of 'Low'.

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 group occurs on rock substratum. A change towards a sedimentary or soft rock substratum would lead to the direct loss of suitable attachment and the loss of biotope and their associated communities. Resistance is assessed as 'None'. Resilience is 'Very low' as it represents a permanent change. Therefore, sensitivity is assessed as '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 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 hard rock biotopes.

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 are epifauna or epiflora occurring 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: High A: High C: Medium	Medium Q: High A: Medium C: Medium

This biotope is found on the upper intertidal shore, an area easily accessible by humans. Individual *Fucus* specimens are very 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 & Crumrine (1994) investigated the effect of trampling on a number of algal species, including *Fucus distichus*, on an intertidal rocky shore 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, 2005b; Tyler-Walters & Arnold, 2008).

Sensitivity assessment. Abrasion through activities such as trampling will probably cause a reduction in *Fucus distichus* and *Fucus spiralis* abundance and a consequent reduction in a loss of community complexity. The evidence for this pressure has resulted in 'Low' resistance being allocated to this pressure. Resilience is assessed as 'Medium'. Overall the biotope has a 'Medium' sensitivity to the pressure.

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 occur on rock that 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: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

Light is an essential resource for all photoautotrophic organisms. Changes in suspended particulate matter (SPM) affect water clarity and have a direct impact on the photosynthesising capabilities of fucoids. Irradiance below the light compensation point of photosynthetic species can compromise carbon accumulation (Middelboe *et al*., 2006). A decrease in light penetration in the Kiel Fjord has caused an upwards shift of the lower depth limit of *Fucus vesiciulosus* (Rohde *et al*., 2008).

Kõuts *et al*. (2006) found decreases in light intensity in the vicinity of the dredging site resulted in the net decline of *Fucus vesiculosus* biomass. Increased siltation can also cover the frond surface of fucoids with a layer of sediment further reducing photosynthesis and growth rate. Sediment deposition can also interfere with attachment of microscopic stages of seaweeds reducing recruitment. Berger *et al*. (2003) demonstrated that both interference with sediment during settlement, and burial after attachment, were significant causes of mortality for *Fucus vesiculosus* germlings (see 'siltation' pressures).

Both *Fucus distichus* and *Fucus spiralis* would be affected by turbidity as outlined above when immersed. However, both *Fucus distichus* and *Fucus spiralis* can spend up to 90% of their time emersed and can photosynthesise more effectively in air than in water (Madsen & Maberly, 1990).

This does not mean that there would not be any negative impacts on these two characterizing species. But a change to this pressure at the benchmark is not likely to have any significant negative impacts on the characterizing species. It is likely that other species within this biotope who can only feed at high water may be more negatively affected. In particular filter feeding organisms will have their feeding apparatus clogged with suspended particles leading to a reduction in total ingestion and a reduced scope for growth especially since cleaning the feeding apparatus is likely to be energetically expensive.

Sensitivity assessment. Changes in suspended solids reducing water clarity are not likely to have a negative impact on the biotope. Resistance is assessed as 'High', resilience is assessed as 'High' and the biotope is assessed as 'Not sensitive ' at the benchmark level.

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

Frond lengths of algae on exposed shores tend to have a smaller average size than those on sheltered shores (Lewis, 1986; Menge, 1976). The forms of *Fucus distichus* and *Fucus spiralis* found within this biotope are shorter in length than those found in more sheltered locations. Frond length for adult *Fucus distichus* ranging between 6-10 cm. Scott *et al.* (2001) noted that *Fucus spiralis* f. *nanus* is significantly shorter than *Fucus spiralis.* If the deposition of 5 cm of sediment occurred at high tide, the sediment would cover a significant proportion of the algae within this biotope. It would also smother a large proportion of the other organisms within the biotope. The outcome of which would be the inhibition of photosynthesis in the algae. The feeding activity and movements of herbivores might be limited (Airoldi & Hawkins, 2007; Schiel *et al.*, 2006), and the productivity of filter feeding organisms would also be stopped due to lack of water flow. Respiration would be severely limited if not altogether stopped in most organisms. If smothering occurs at low tide when the algae are lying flat on the substratum, then all of the fauna and flora within this biotope would be covered by the deposition of fine material at the level of the benchmark.

Sediment deposition would also have a significant impact on the ontogeny of the characterizing species. Sediment deposition is commonly assumed to reduce macroalgal recruitment by three main mechanisms: (1) pre-emption of space, reducing the amount of substrate 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). Berger *et al*. (2003) demonstrated that both interference with sediment during settlement, and burial after attachment, were significant causes of mortality for *Fucus vesiculosus* germlings. As all fucoids are broadcast spawners with external fertilization (Engel *et al*., 2005), and similar processes for recruitment to the shore it is likely that the two characteristic species for this biotope would encounter similar issues with sedimentation.

Sensitivity assessment. Smothering by 5 cm of sediment is likely to completely cover the species in the biotope, preventing photosynthesis and respiration. The individual important species have a high resistance to smothering. However, this biotope occurs in extremely exposed locations and wave action is likely to mobilize and remove the deposited sediment within a few tidal cycles allowing the biological community to return to normal. Therefore, resistance has been assessed as 'High' so that resilience has been assessed as 'High' and the biotope is probably 'Not sensitive' at the level of the benchmark.

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

The impact of 30 cm of fine material deposited onto the seabed in a single event will have the same immediate effect as smothering by 5 cm. Photosynthesis, reproductive processes, respiration and uptake of food and nutrients are will be almost entirely inhibited. The weight of the sediment may also have a negative impact through compression and crushing of some more delicate organisms, and resultant scour may damage fronds or remove ephemeral seaweeds and gastropods.

Sensitivity assessment. The highly wave exposed conditions of this biotope means that it is likely that sediment will be quickly remobilized and removed from the shore. However, a resistance of 'Medium' is suggested to represent the resultant scour. Resilience is probably 'High' so that sensitivity is assessed as 'Low'.

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

Not assessed

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

No evidence was found

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

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

Species characterizing this habitat have no hearing perception but vibrations may cause an impact, however, no studies exist to support 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

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

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The important characterizing species within this biotope are not cultivated or translocated. This pressure is therefore considered 'Not relevant' to this biotope group.

Introduction or spread of invasive non-indigenous species	Medium Q: Low A: NR C: NR	Medium Q: High A: High C: Medium	Medium Q: Low A: Low C: Low

Thompson & Schiel (2012) found that native fucoids show high resistance to invasions by the Japanese kelp *Undaria pinnatifida*. Stæhr *et al*. (2000) determined that the invasion of *Sargassum muticum* could affect local algal communities through competition mainly for light and space. The recent introduction of *Gracilaria vermiculophylla* to the Baltic Sea prompted an investigation into its possible impacts on *Fucus vesiculosus*. Hammann *et al.* (2013) found that in the Baltic Sea *Gracilaria vermiculophylla* could impact *Fucus vesiculosus* through direct competition for recourses, decreasing the half-life of germlings, and increasing the level of grazing pressure. To date, *Gracilaria vermiculophylla* has only been recorded in Northern Ireland, and not on mainland Britain. The introduction of this species to intertidal rocky shores around the British Isles could have negative impacts on native fucoids, and could become relevant to this specific biotope.

Sensitivity assessment. Although evidence often indicates that invasive non-native species (INIS) could have a negative impact native species, no evidence was found on the impacts of INIS on the characterizing species of this biotope. Evidence regarding other fucoids indicates that some mortality of characterizing species can occur through direct and indirect consequences of INIS being present. Resistance has, therefore, been assessed as 'Medium' since invasive species have the potential to alter the recognizable biotope. Resilience has also been assessed as 'Medium' resulting in an overall 'Medium' sensitivity score.

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

Very little is known about infections in *Fucus* (Olsenz, 2011). Coles (1958) identified parasitic nematodes that caused galls on *Fucus serratus* in the south west of Britain. But to date, no mortalities have been associated with the introduction of microbial pathogens. Torchin *et al.* (2002) suggest that there is potential for increased biotic interactions with parasites or pathogens in many marine systems.

Sensitivity assessment. Both resistance and resilience are assessed as 'High'; the biotope is, therefore, probably 'Not Sensitive' to this pressure. However, the assessment has a low confidence score as more research is needed into the effects of a microbial pathogen on *Fucus vesiculosus*.

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

Fucoids may be directly removed or damaged by static or mobile gears that are targeting other species. These direct, physical impacts 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.

Many macroalgae are harvested for their alginates, which are used in the cosmetic and pharmaceutical industries, for agricultural supply, water treatment, and for human food and health supplements (Bixler & Porse, 2010). There is little information available as to whether either *Fucus distichus* or *Fucus spiralis* are collected for these reasons. However, if the characteristic species are collected the effects are likely to be very similar to that caused by the removal of other Fucoids from intertidal rocky shores.

The commercial harvest removes seaweed canopies which will have important effects on the wider ecosystem. Stagnol *et al.* (2013) investigated the effects of commercial harvesting of intertidal fucoids on ecosystem biodiversity and functioning. The study found that the removal of macroalgae affected the metabolic flux of the area. Flows from primary production and community respiration were lower on the impacted area as the removal of the canopy caused changes in temperature and humidity conditions. Suspension feeders were the most affected by the canopy removal as canopy-forming algae are crucial habitats for these species, most of them being sessile organisms. Other studies confirm that loss of canopy had both short and long-term consequences for benthic communities in terms of diversity resulting in shifts in community composition and a loss of ecosystem functioning such as primary productivity (Lilley & Schiel, 2006; Gollety *et al.*, 2008). Removal of the canopy caused bleaching and death of understorey red turfing algae. Stagnol *et al.* (2013) observed *Patella vulgata* recruiting in bare patches of disturbed plots. Experimental studies have shown that limpets control the development of macroalgae by consuming microscopic phases (Jenkins *et al.*, 2005) or the adult stages (Davies *et al.*, 2007). The increase in *Patella vulgata* abundance could thus limit the recruitment and growth of *Fucus serratus* on the impact zone.

Due to the intolerance of macroalgae communities to human exploitation, the European Union put in place a framework to regulate the exploitation of algae establishing an organic label that implies that 'harvest shall not cause any impact on ecosystems' (no. 710/2009 and 834/2007).

Sensitivity assessment. The removal of *Fucus distichus* and *Fucus spiralis* would have an impact on the biotope in question, as they are the characterizing species. 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', giving an overall sensitivity score of 'Medium'. However, as there is no direct evidence regarding their removal from intertidal shore the assessment is precautionary and made with 'Low' confidence.

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

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The characterizing species *Fucus distichus* and *Fucus spiralis* create a dominant turf within this biotope. If these characterizing species were removed incidentally from this biotope as by-catch when other species are being targeted, then the loss of these 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’, giving an overall sensitivity score of ‘Medium’.

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