Ascophyllum nodosum and *Fucus vesiculosus* on variable salinity mid eulittoral rock

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

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2015-09-30

This review can be cited as:
Perry, F., d'Avack, E., & Hill, J., 2015. [Ascophyllum nodosum] and [Fucus vesiculosus] on variable salinity mid eulittoral rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. DOI https://dx.doi.org/10.17031/marlinhab.78.1

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***Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock**
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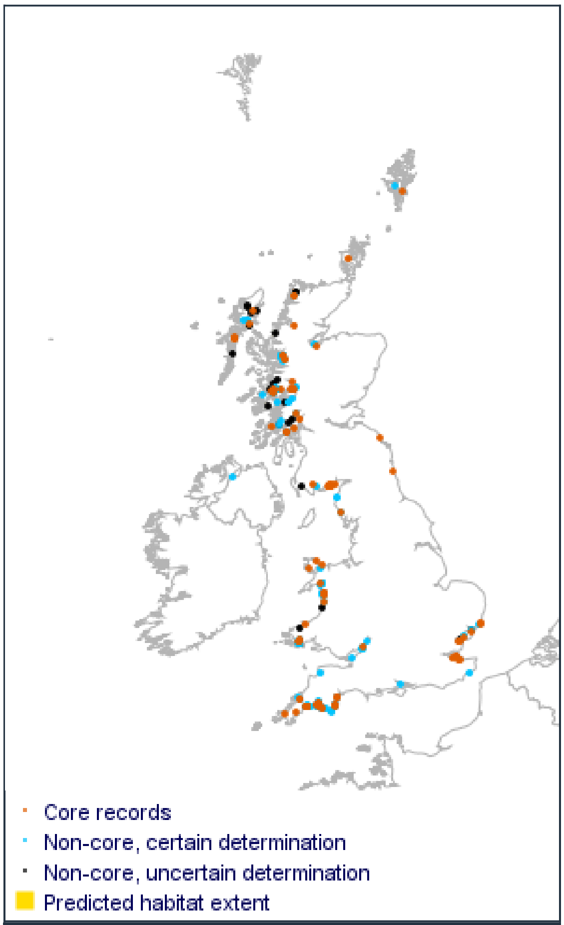

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Frances Perry, Emilia d'Avack, & Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.324	*Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock
JNCC 2015	LR.LLR.FVS.AscVS	*Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock
JNCC 2004	LR.LLR.FVS.AscVS	*Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock
1997 Biotope	LR.SLR.F.Asc.VS	*Ascophyllum nodosum* and *Fucus vesiculosus* on variable salinity mid eulittoral rock

Description

Very sheltered to extremely sheltered mid eulittoral bedrock, boulders or cobbles subject to variable salinity characterized by an impoverished community dominated by a mixture of the wracks *Ascophyllum nodosum* and *Fucus vesiculosus*. Underneath the canopy are a few green seaweeds including *Ulva intestinalis* and *Cladophora* spp., while the red seaweed *Polysiphonia lanosa* can be found as an epiphyte on *A. nodosum*. On the rock and among the boulders are the winkles *Littorina littorea* and *Littorina saxatilis*, the crab *Carcinus maenas*, the barnacles *Semibalanus balanoides* and *Elminius modestus* and even the occasional mussel *Mytilus edulis*. Among the seaweeds and underneath the boulders a variety of gammarids can be found (see Connor *et al*., 2004).

Depth range

Upper shore, Mid shore, Lower shore, 0-5 m

Additional information

This biotope usually lies below the *Fucus spiralis* biotope (Fspi.VS) or the Fucus ceranoides dominated biotopes (Fcer) and above the variable salinity *Fucus serratus* dominated biotope (Fserr.VS), although on some shores a narrow zone of *Fucus vesiculosus* (Fves) may occur immediately above the *Ascophyllum nodosum*. With increasing wave exposure the *Ascophyllum nodosum* canopy can be more dense (Asc.FS). *Ascophyllum nodosum* can reach an age of 25 years and the communities are usually stable. *Fucus vesiculosus* or *Fucus serratus* can occur in patches where the *Ascophyllum nodosum* has been removed (taken from Connor et al., 2004).

Listed By

- none -

Further information sources

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Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The combination of physical characteristic within this biotope lead to an impoverished biological community. The characterizing species are *Ascophyllum nodosum* and *Fucus vesiculosus*, whose fronds create a dense canopy. Other species of algae also found within this biotope include; the red seaweed *Polysiphonia lanosa*, a common epiphyte on *Ascophyllum nodosum*, and the green seaweeds *Ulva intestinalis* and *Cladophora* spp.. Two species of barnacle can be found within this biotope, the native *Semibalanus balanoides* and the non-native species *Elminius modestus*. The dominant grazing species are the littorinids *Littorina littorea* and *Littorina saxatilis*. The crab *Carcinus maenas* is the dominant predator within this biotope. The mussel *Mytilus edulis* is found occasionally within cracks and fissures and Gammarids can be found in more sheltered micorhabitats (Connor *et al*., 2004).

Ascophyllum nodosum and *Fucus vesiculosus* are the key structuring species of this biotope. These two species act as ecosystem engineers and the canopies that their fronds create modify habitat conditions. The canopy provides protection from desiccation for the various underlying seaweeds in addition to providing a substratum for epifauna and being the primary food resource for grazers. This can facilitate the existence and survival of other intertidal species and therefore strongly influencing the structure and functioning of intertidal ecosystems (Jenkins *et al*., 2008).

Resilience and recovery rates of habitat

Ascophyllum nodosum has been reported to survive for over 100 years in areas free from ice scour (Åberg 1992). However, individual fronds are more likely to last for 15 -20 years after which they will break off, and new fronds will regenerate from the holdfast. The average age within populations of *Ascophyllum nodosum* is high, and there is little population turn over (Schiel & Foster, 2006). *Ascophyllum nodosum* takes five years to become sexually mature (Sundene 1973). Within a mature stand of *Ascophyllum nodosum* as many as 10^9 eggs 1 m^2/year may be produced (Åberg & Pavia 1997). However, Dudgeon & Petraitis (2005) estimate that it will take a minimum of 13 years for an individual to replace itself. This is due to high mortality rates of germlings. Lazo *et al.* (1994) found that predation by grazers can reduce annual recruit survival rates to 0.01%. Other factors which affect the survival rates of recruited *Ascophyllum nodosum* include their susceptibility to sedimentation (Airoldi, 2003), ability to tolerate desiccation at low tide (Brawley & Johnson, 1991) and inter and intra specific density dependent competition of germlings (Choi & Norton, 2005).

The investigation by Choi & Norton (2005) looks at the competitive interactions between the germlings of *Ascophyllum nodosum* and *Fucus vesiculosus*. Experiments undertaken on the Isle of Man and in a laboratory, found that with an increasing density of germlings, growth rates of both species decreased. Of the two species, *Ascophyllum nodosum* germlings grew slower and were least competitive in mixed cultures. This finding was mirrored in earlier experiments undertaken by Sundene (1973). Sundene (1973) noted that the production of sexual cells in *Ascophyllum nodosum* was as rapid as it was in *Fucus vesiculosus*, but that is was the growth rates of *Ascophyllum nodosum* which led to *Fucus vesiculosus* being more competitive on the shore. Choi & Norton (2005) also found that the presence of *Fucus vesiculosus* increased the survival of *Ascophyllum nodosum* when exposed to desiccation stress. This showed that under different environmental conditions the presence of a mixed culture could either facilitate germling survival or lead to competitive exclusion (Choi & Norton, 2005). Competition is reversed in mature ecosystems where

Ascophyllum nodosum plants can out-compete Fucoids (Keser *et al.*, 1981).

Lamote & Johnson (2008) studied temporal and spatial variation in recruitment of fucoid algae (including *Ascophyllum nodosum*). They found that recruitment to artificial substrata located in different micro-habitats along a semi-exposed shore were noticeably different. Under the fucoid canopy in the study area, recruitment was 10-50 times greater than it was on exposed surfaces and in tide pools. To determine if this difference was due to lower levels of mortality under the canopy or to restricted distribution capacity, newly settled recruits from under the canopy were relocated to alternative microhabitats. Mortality rates of the relocated germlings were higher in the more exposed locations, however the difference was not great enough to explain the observed difference in number of germlings within the two different microhabitats. Lamote & Johnson (2008) concluded that the number of recruits was greater from under the fucoid canopy because of restricted distribution abilities.

Ascophyllum nodosum has a low dispersal capacity which means re-colonization of a shore after a mass mortality event can be extremely slow. It can also limit the speed at which the species recovers from a partial die back. *Ascophyllum nodosum's* poor dispersal ability has been widely acknowledged and the reasons behind it have been well studied. Experiments on the effect of wave action on *Ascophyllum nodosum* showed that a low-velocity wave can remove 99% of 15 minute old zygotes from experimental tiles Vadas *et al.* (1990). Further investigation with the use of refuges found that 75-90% of zygotes as old as four hours could be removed by a single wave. Current speeds of over 20 cm/s makes attachment success of *Ascophyllum nodosum* very poor (Vadas *et al.*, 1992). Therefore, calm conditions are required for successful recruitment in *Ascophyllum nodosum.*

The current and historic commercial interest in *Ascophyllum nodosum* has resulted in recovery times for this species being well documented. Keser *et al.* (1981) recorded the levels of re-growth exhibited by *Ascophyllum nodosum* and *Fucus vesiculosus* after harvesting activity in Maine. Harvesting was simulated by cutting fronds to three different lengths; frond removed to the holdfast, 15 cm from the holdfast and 25 cm from the holdfast. Subsequent harvesting was repeated annually for three years. The experiment was carried out at eight sites, six of which were in sheltered areas. Re-growth of *Ascophyllum nodosum* was found to be dependent on a number of variables. These included; the age structure of the population, the extent and pattern of branching with a clump, the presence or absence of grazers (importantly *Littorina littorea*), and the environmental conditions (recovery was found to be more rapid in estuaries) (Keser *et al.*, 1981). Of the fronds which were cut back to the holdfast, only those within sheltered, estuarine and grazer free conditions showed any re-growth. More mature *Ascophyllum nodosum* fronds cut back to 15 cm and 25 cm within a sheltered site showed some re-growth; however there were high rates of mortality. The lack of re-growth was suggested to be caused by a lack of functional growing points found towards the bottom of the frond in older individuals. Almost all (95%) of young *Ascophyllum nodosum* individuals cut back to 15 cm and 25 cm re-grew. The detrimental impact of annual harvests on *Ascophyllum nodosum* populations were shown through the results of this investigation. In almost all populations measured within the experiment, repeat harvests resulted in lower biomass yields (Keser *et al.*, 1981).

Slow re-growth of *Ascophyllum nodosum* after harvesting from the holdfast has also been reported by Baardseth (1970). Areas where *Ascophyllum nodosum* has been harvested from the bed by scrapping it from the substratum was found to destroy beds for extended periods of time. On shores where *Ascophyllum nodosum* had been removed, re-colonization was dominated by *Fucus vesiculosus*, with very little recovery of *Ascophyllum nodosum*. When artificial substrata, such as sea walls, are introduced into an intertidal area *Ascophyllum nodosum* can take many years to colonize it. When the colonization and succession of a breakwater built in Norway was recorded the first species to appear were *Fucus vesiculosus* and *Fucus spiralis* (Baardseth, 1970). It took two years for occasional *Ascophyllum nodosum* individuals to appear on the breakwater, and after eight years there was still no distinct *Ascophyllum nodosum* zone. Another breakwater studied had an established *Ascophyllum nodosum* zone after 30 years (Knight & Parke, 1950).

Printz (1956) also carried out harvesting experiments where fronds were cut back to 25 cm, 15 cm and 5 cm. Results showed that those individuals that had been cut back to 25 cm had an 'abundance of new shoots' and had grown to 30-35 cm in length after a year. Those algae which had been trimmed back to 5 cm showed almost no change a year after a harvesting event had been simulated. When the 5 cm individuals where re-visited three years after the harvesting event they were still almost unaltered. The reasons for the lack of re-growth were attributed to the lack of regenerative tissue found in the older flesh found further down the thallus (Printz, 1956).

Mass mortality events caused by changes in the physical environment have been observed in *Ascophyllum nodosum.* A total mortality event of an *Ascophyllum nodosum* population occurred within the Long Island Sound in 1984 (caused by water temperatures from two power plant thermal discharge pipes exceeding 28 ^{o}C) (Keser *et al*., 2005). From 1984 onwards temperatures at the site fluctuated with the opening of a third thermal discharge pipe and the closing and reopening of the pipes all three pipes. However, in the 18 years since the mortality event and the end of Keser *et al*'s. (2005) study, there has been no recovery of the population. Keser *et al.* (2005) reported that similar mortality events have been observed near other power plant thermal discharge pipes in Maine (Vadas *et al*., 1978) and Massachusetts (Wilce *et al*., 1978).

Printz (1956) indicated that a number of other studies (unreferenced in the paper) reported similar findings. Other studies which have concluded that *Ascophyllum nodosum* takes long periods of time to recover from removal include Bertness *et al.* (2002), Jenkins *et al*. (1999, 2004), and Petraitis & Dudgeon (2005). Ingólfsson & Hawkins (2008) sum up the findings from previous studies on *Ascophyllum nodosum* re-colonization times within their discussion where they state 'the partial recovery of the *Ascophyllum nodosum* canopy after a 12 year period is consistent with some very early studies'. The twenty year study untaken by Ingólfsson and Hawkins (2008) found that after removing an *Ascophyllum nodosum* community, the canopy could return within the study time period, yet the under storey communities had still not recovered after 20 years. There is a considerable amount of evidence that suggests that when *Ascophyllum nodosum* fronds are cut higher up the thallus recovery times are reduced considerably to two to three years (Ang *et al*., 1996; Fegley, 2001; Keser *et al*., 1981; Sharp, 1987; Ugarte *et al*., 2006) (taken from Phillipi *et al*., 2014). However the effect of this kind of canopy removal on the understory community is not known and neither is the recovery time.

Svensson *et al.* (2009) compared the population growth of *Ascophyllum nodosum* from two shores, one on the Isle of Man and one from Sweden. Although there were significant differences in the demography and appearance of the two populations, the phenotypic plasticity and sensitivities of the two populations were very similar. This is curious as the poor dispersal abilities of *Ascophyllum nodosum* means that minimal recruitment would occur between the two study populations. In addition, the geographical locations of the two shores mean that the environmental factors are significantly different and provide different selective pressures. It was suggested that the combination of different selective pressures and lack of genetic crossover could lead some level of allopatric speciation. However, this was not the case, which suggests that *Ascophyllum nodosum* has significant life history plasticity and can able to withstand 'very large environmental variation'

(Svensson *et al*., 2009). The results from Svensson *et al*., (2009) also suggest that pressures which affect the survival or growth of large sexually reproductive *Ascophyllum nodosum* could have severe negative effects on regional abundance and biomass of the species.

Fucus vesiculosus growth rates can vary both spatially and temporally (Lehvo et al., 2001). Temperature, exposure, and light availability are some of the factors which cause these changes in growth rates (Strömgren, 1977, Knight & Parke, 1950, Middelboe et al., 2006). Strömgren (1977) investigated the effect of short-term increases in temperature on the growth rate of Fucus vesiculosus. It was found that the growth rate of the control sample kept at 7°C was 20 times lower than the sample introduced to temperatures of 35 °C (Strömgren 1977). When the effect of temperature was investigated on the shore, relative growth rates in summer were found to be as high as 0.7% / day in summer, compared to less than 0.3% / day in winter (Lehvo et al., 2001). For macroalgae the trend is for shorter individuals in situations with greater wave exposure (Lewis, 1961, Stephenson & Stephenson, 1972, Hawkins *et al*., 1992, Jonsson *et al*., 2006). *Fucus vesiculosus* also comply with this trend, and growth rates mirror this difference in physiology. On Sgeir Bhuidhe, an exposed shore in Scotland, *Fucus vesiculosus* grew on average 0.31 cm / week. On a sheltered Scottish shore the average increased to 0.68 cm / week (Knight & Parke, 1950).

In *Fucus vesiculosus t*he development of the receptacles takes three months from initiation to gamete release (Knight, 1947). On British shores, receptacles are initiated around December and may be present until late summer (Knight, 1947). *Fucus vesiculosus* is dioecious, and gametes are generally released into the seawater under calm conditions (Mann, 1972; Serrão et al., 2000) and the eggs are fertilized externally to produce a zygote. Serrão *et al.* (1997) determined that the wrack had a short-range dispersal capacity. Under calm conditions in which eggs are released, most eggs fall in the immediate vicinity of the parent plants. The egg becomes attached to the rock within a few hours of settlement and adhere firmly enough to resist removal by the next returning tide and germling may be visible to the naked eye within a couple of weeks (Knight & Parke, 1950). Despite the poor long range dispersal, the species is highly fecund often bearing more than 1000 receptacles on each plant, which may produce in excess of one million eggs. On the coast of Maine, sampling on three separate occasions during the reproductive season revealed 100% fertilization on both exposed and sheltered shores (Serrão *et al*., 2000). Fertilization is thus not considered as a limiting factor in reproduction in this species (Serrão *et al*., 2000).

Mortality is extremely high in the early stages of germination up to a time when plants are 3 cm in length and this is due mostly to mollusc predation (Knight & Parke 1950). While *Fucus vesiculosus* may resist some degree of environmental stress, their long-term persistence depends on their reproductive ability as well as the survival and growth of early life history stages (germlings) that are generally more susceptible to natural and anthropogenic stressors than adults (Steen, 2004; Fredersdorf *et al*., 2009). It is therefore necessary to include early life stage responses in the assessment of effects of environmental changes on fucoid algae as only considering fully developed adults specimens may lead to false conclusions (Nielsen *et al*., 2014).

In addition to sexual reproduction, *Fucus vesiculosus* is also able to generate vegetative re-growth in response to wounding. McCook & Chapman (1992) experimentally damaged Fucus vesiculosus holdfasts to test the ability of the wrack to regenerate. The study found that vegetative sprouting of *Fucus vesiculosus* holdfasts made a significant addition to the regrowth of the canopy, even when holdfasts were cut to less than 2 mm tissue thickness. Four months after cutting, sprouts ranged from microscopic buds to shoots about 10 cm long with mature shoots widespread after 12 months. Vegetative re-growth in response to wounding has been suggested as an important mean of recovery from population losses (McLachan & Chen, 1972). The importance of regeneration will depend on the severity of damage, not only in terms of the individuals but also in terms of the scale of canopy removal (McLachan & Chen, 1972).

Genetic diversity can influence the resilience of fucoids in particular when pressure persists over a long period of time. Genetically diverse populations are generally more resilient to changes in environmental conditions compared to genetically conserved populations. Tatarenkov *et al.* (2007) determined a high level of genetic variation in Fucus vesiculosus and extensive phenotypic variations. This could explain why the species is more successful than most fucoid species in colonizing marginal marine environments such as low-salinity estuaries, showing a range of morphological, physiological and ecological adaptations (Tatarenkov *et al.* 2005). Pressures causing a rapid change will have a greater impact as the natural ability of the species to adapt is compromised.

Resilience assessment. If specimens of *Fucus vesiculosus* remain in small quantities it is likely that re-growth will occur rapidly due to efficient fertilization rates and recruitment over short distances. The ability of *Fucus vesiculosus* to re-grow from damaged holdfasts will also aid in recolonization. Recovery is likely to occur within two years resulting in a ‘High’ resilience score. However, if the population is removed (resistance is ‘None’), recovery may take longer, perhaps up to ten years (as seen after the *M.V. Torrey Canyon* oil spill) so the resilience would be scored as ‘Medium’.

Ascophyllum nodosum has low dispersal abilities, high juvenile mortality rates and can take in excess of five years to reach reproductive maturity. If a pressure causes a mass mortality event on a shore an *Ascophyllum nodosum* canopy can take twelve years to recover. This recovery depends on mature populations of the macroalgae in the vicinity from which to recruit. If partial damage occurs to the frond but 15cm - 25 cm remain, then recovery of an individual can occur within two to three years. Evidence suggests that even after the recovery of an *Ascophyllum nodosum* population the understory communities and ecosystem functioning of the area can take in excess of twenty years.

When considering the resilience of this biotope the characterizing species *Ascophyllum nodosum* needs longer periods of time than *Fucus vesiculosus* to recover. Although no experiments have been undertaken within this biotope, the length of time for understory communities to recover within other wave sheltered *Ascophyllum nodosum* habitats is in excess of twenty years. This biotope has an impoverished community, the species within which can recover relatively quickly, so times scales may vary. In conclusion, if only partial damage is done to the characterizing marcroalgae within his biotope then recovery could be quick between two to ten years, giving a resilience of ‘Medium’. However if a pressure causes a mass mortality of the characterizing species the resilience is categorized as ‘Low’.

The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognisable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

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

Schonbeck & Norton (1979) demonstrated that fucoids can increase tolerance in response to gradual change in temperature through a process known as 'drought hardening'. However, acute changes in temperatures may cause damage to macroalgae and other species. Temperature ranges of species may not accurately describe their ability to withstand localized changes in temperature. However, they will display the limits of the species genetic ability to acclimatize to temperatures. Juvenile life stages of organisms can be less tolerant to environmental conditions than more mature stages.

In the north east Atlantic *Fucus vesiculosus* occurs from Northern Russia to Morocco (Powell, 1963). Within this range Fucus vesiculosus can survive in a wide variety of temperatures. *Fucus vesiculosus* is able to tolerate temperatures as high as 30 °C (Lüning,1990) and did not show any sign of damage during the extremely hot UK summer of 1983, when average temperatures were 8 °C hotter than normal (Hawkins & Hartnoll, 1985). *Fucus vesiculosus* also tolerates extended periods of freezing in the northern part of its range.

Ascophyllum nodosum is found in the middle of its range in the British Isles, with populations in the north east Atlantic as far south as Portugal and extending north to the White Sea. *Ascophyllum nodosum* is unlikely to be affected by a short-term change of 5°C, as it was not damaged during the unusually hot summer of 1983 when the average temperature was 8.3°C higher than normal (Hawkins & Hartnoll, 1985). *Ascophyllum nodosum* can tolerate certain levels of exposure as they are regularly exposed to rapid and short-term variations in temperature. Both exposure at low tide or rising tide on a sun-heated shore involves considerable temperature changes, and during winter the air temperature may be far below freezing point. Growth of *Ascophyllum nodosum* has been measured between 2.5 and 35°C with an optimum between 10 and 17°C (Strömgren, 1977). *Ascophyllum nodosum* can be damaged by thermal pollution if the water temperature remains above 24°C for several weeks (Lobban & Harrison, 1997), and temperatures exceeding 27°C cause direct mortality (Keser *et al.*, 2005). Water temperature is an excellent predictor of gamete release in *Ascophyllum nodosum* (Bacon & Vadas, 1991). Consequently changes in temperatures could impact on gamete release. Investigations into the tolerance of *Ascophyllum nodosum* germlings from Norway, to temperatures between 7°C -17°C found that there was no difference in survival rates within the given range (Steen & Rueness, 2004). Germination of *Ascophyllum nodosum* has been recorded between the temperatures of 4°C - 23°C.

Other species found within this biotope are probably tolerant of temperature changes at the benchmark level as they are widely distributed in the UK. The balance of interactions between fucoids and barnacles changes with geographical location. Warmer conditions further south than the British Isles favour greater penetration of barnacles into sheltered locations (Ballantine, 1961 cited in Raffaelli & Hawkins, 1996). Warmer conditions are also likely to favour *Chthamalus* spp. rather than *Semibalanus balanoides* although a change of species will not alter the function of the biotope. Those species which are mobile, such as the littorinids and *Carcinus maenas* have the opportunity to move away from areas if physical conditions become too harsh

Sensitivity assessment. The characterizing species *Fucus vesiculosus* and *Ascophyllum nodosum* are found in the middle of their habitat range in the British Isles. Although the range of these species can extend down to Portugal if the temperature changes are acute and occur over a short period leaving no time for acclimation then there could be some damage caused to the microalgae's. However if the changes are more gradual then the algae may have time to acclimate which would not produce any significant negative impact. The benchmark scenario which is likely to cause the most stress to this biotope is an increase of 5°C for one month. The sensitivity assessment for this scenario gives both resistance and resilience a score of 'Medium'. Meaning that the biotope has a 'Medium' sensitivity to this pressure at the benchmark.

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

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Other species found within this biotope are moderately tolerant of temperature changes at the benchmark level. *Elminius modestus*, a non-native barnacle, is commonly found within this biotope. It is only found as far north as the Shetland Islands in the British Isles and may be negatively affected by a decrease in temperature. However, colder conditions are likely to favour the native *Semibalanus balanoides* (already found in this biotope) which would fill the functional niche left by *Elminius modestus*. Those species which are mobile, such as the littorinids and *Carcinus maenas* have the opportunity to move away from areas if physical conditions become too harsh.

Sensitivity assessment. The characterizing species *Fucus vesiculosus* and *Ascophyllum nodosum* are found in the middle of their habitat range in the British Isles. Although the range of these species can extend up to the White Sea if the temperature changes are acute and occur over a short period leaving no time for acclimation then there could be some damage caused to the microalgae's. However, if the changes are more gradual then the algaes may have time to acclimate which would not produce any significant negative impact. The benchmark scenario which is likely to cause the most stress to this biotope is an decrease of 5 °C for one month. The sensitivity assessment for this scenario gives both resistance and resilience a score of 'Medium'. Meaning that the biotope has a 'Medium' sensitivity to this pressure at the benchmark.

Salinity increase (local)	None Q: High A: High C: Medium	High Q: High A: Medium C: Medium	Medium Q: High A: Medium C: Medium

Intertidal macroalgaes often experience large but short-term changes in salinities Lobban & Harrison (1997). Salinities within these habitats vary due to weather conditions such as rain fall at low tide and evaporation from rock pools on hot days. Intertidal shores within estuarine environments can also experience considerable short-term changes in salinities. However, intertidal macroalgae tolerances to longer term changes in salinities can be minimal and can quickly reduce photosynthetic abilities and cause mortality.

This biotope is only found in variable salinity conditions (18 – 40 psu) (Connor *et al.*, 2004), an increase in the salinity would create fully marine conditions (30 – 40). Investigations into the salinity tolerances of both *Ascophyllum nodosum* and *Fucus vesiculous* in laboratory controlled conditions found that the photosynthetic capabilities of both species decreased with reduced salinities. *Ascophyllum nodosum* tolerated 7 days at salinities of 5, and all samples died after 15 days at salinities of 5 (Connan & Stengel, 2011).

Fucus vesiculosus is well adapted to cope with varying salinities and can grow in full saline to brackish conditions. Indeed *Fucus vesiculosus* is the dominant large perennial seaweed in the Baltic Sea growing in salinities down to 4 psu (Kautsky, 1992). Bäck *et al.* (1991) compared *Fucus vesiculosus* individuals from Atlantic and the Baltic populations. Both populations were able to withstand wide range of salinities in laboratory cultures, yet some differences were recorded. The Atlantic population showed better growth in higher salinities and virtually no growth at 5 ppt. Those individuals kept at 5 ppt mortality occurred after 7 weeks. In contrast the Baltic wracks grew better in conditions with lower salinities. Growth was negligible at the highest tested salinity (45 ppt). Back *et al.*, (1991) demonstrate that sensitivity of *Fucus vesiculosus* to changes in salinity differ between populations.

Serrao *et al.* (1996a) found that lower salinities can negatively affect both the fertilization rates and recruitment success of *Fucus vesiculosus.* Serrao *et al.* (1996a) also concluded that the osmotic tolerances of *Fucus vesiculosus* gametes limit the species distribution in the Baltic Sea. These studies show that low salinities limit the recruitment and fertilization success of fucoids. There is also evidence suggesting that reduced salinities can influence the rate of receptacle maturation in fucoids (Munda, 1964). Rate of fructification in both *Ascophylum nodosum* and *Fucus vesiculosus* has been measured to increase in diluted seawater (Munda, 1964).

Baardseth (1970) noted that *Ascophyllum nodosum* is euryhaline with a salinity tolerance of about 15 to 37 psu. Studies undertaken by Chock & Mathieson (1979) found *Ascophyllum nodosum* plants in the laboratory photosynthesised at salinities from 0 to 40 psu although the long-term effects within this range were not evaluated. No information could be found on the effects of an increase in salinity on the reproductive cycle of *Ascophyllum nodosum.*

A number of the other species within the biotope can also be found within rockpools where hyper saline conditions can be found (Newell, 1979). Consequently an increase in salinity within the benchmark of this pressure would not cause any significant mortalities. *Semibalanus balanoides* can tolerate salinities between 12 and 50 psu, below and above this cirral activity ceases (Foster, 1970). *Mytillus edulis* is considered to be tolerant of a wide range of salinities (Holt *et al.*, 1998). *Littorina littorea*, *Littorina saxatilis* and *Carcinus maenus* are mobile species and have the ability to move to suitable conditions on the shore.

Sensitivity assessment. An increase in salinity for this biotope would mean salinity levels would become fully marine. All species within this biotope are tolerant to fully marine conditions and mortality events would not occur, however the biotope would be lost as the occurrence of fully marine conditions would encourage further species and create a different fully marine biotope. The resistance of this biotope is given as ‘None’; the resilience is ‘Medium’ as although the biotope is likely to have changed the characterizing species are likely to be very similar. This would allow relatively quick recovery from this pressure. The sensitivity of this biotope to the pressure at this benchmark is ‘Medium’.

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

Intertidal macroalgae often experience large but short-term changes in salinities Lobban & Harrison (1994). Salinities within these habitats vary due to weather conditions such as rain fall at low tide and evaporation from rock pools on hot days. Intertidal shores within estuarine environments can also experience considerable short-term changes in salinities. However, intertidal macroalgae tolerances to longer term changes in salinities are minimal and can quickly reduce photosynthetic abilities and cause mortality.

This biotope is only found within variable salinity conditions (18 – 40 psu) (Connor *et al.*, 2004). If the salinity regime were to decrease by a category then it would become reduced salinity (18 – 30 psu). Investigations into the salinity tolerances of both *Ascophyllum nodosum* and *Fucus vesiculous* in laboratory controlled conditions found that the photosynthetic capabilities of both species decreased with reduced salinities.

Fucus vesiculosus is well adapted to cope with varying salinities and can grow in full saline to brackish conditions. Indeed *Fucus vesiculosus* is the dominant large perennial seaweed in the Baltic Sea growing in salinities down to 4 psu (Kautsky, 1992). Bäck *et al.* (1991) compared *Fucus vesiculosus* individuals from Atlantic and the Baltic populations. Both populations were able to withstand wide range of salinities in laboratory cultures, yet some differences were recorded. The Atlantic population showed better growth in higher salinities and virtually no growth at 5 ppt. Those individuals kept at 5 ppt mortality occurred after 7 weeks. In contrast the Baltic wracks grew better in conditions with lower salinities. Growth was negligible at the highest tested salinity (45 ppt). Back *et al.*, (1991) demonstrate that sensitivity of *Fucus vesiculosus* to changes in salinity differ between populations.

Serrao *et al.* (1996a) found that lower salinities can negatively affect both the fertilization rates and recruitment success of *Fucus vesiculosus*. Serrao *et al.* (1996a) also concluded that the osmotic tolerances of *Fucus vesiculosus* gametes limit the species distribution in the Baltic Sea. These studies show that low salinities limit the recruitment and fertilization success of fucoids. There is also evidence suggesting that reduced salinities can influence the rate of receptacle maturation in fucoids (Munda, 1964). Rate of fructification in both *Ascophylum nodosum* and *Fucus vesiculosus* has been measured to increase in diluted seawater (Munda, 1964).

Ascophyllum nodosum is euryhaline with a salinity tolerance of about 15 to 37 psu (Baardseth, 1970). The species can also withstand periodic emersion in freshwater (Baardseth, 1970) and frequently inhabits estuaries where salinity is variable. Doty & Newhouse (1954) reported *Ascophyllum nodosum* from estuarine waters with a maximum salinity of 17.3 psu and a minimum of 0 psu. Chock & Mathieson (1979) found *Ascophyllum nodosum* plants in the laboratory photosynthesised at salinities from 0 to 40 psu although the long-term effects within this range were not evaluated. In the Teign Estuary in South Devon *Ascophyllum nodosum* inhabits areas subject to salinities as low as 8 psu (Laffoley & Hiscock, 1993). Investigations into the salinity tolerance of *Ascophyllum nodosum* in laboratory controlled conditions found that the photosynthetic capabilities of this species decreased with reduced salinities. *Ascophyllum nodosum* tolerated 7 days at salinities of 5, and all samples died after 15 days at salinities of 5 (Connan & Stengel, 2011). There is some evidence to suggest that reduced salinities can influence the rate of receptacle maturation in fucoids (Munda, 1964). Rate of fructification in *Ascophyllum nodosum* has been measured to increase in diluted seawater (Munda, 1964).

A number of the other species within the biotope can also be found within rockpools where hyposaline conditions can be found (Newell, 1979). Consequently a decrease in salinity within the benchmark of this pressure would not cause any significant mortalities. *Semibalanus balanoides* can tolerate salinities between 12 and 50 psu, below and above this cirral activity ceases (Foster, 1970). *Elminius modestus* is more tolerant of reduced salinities than *Semibalanus balanoides* (Fish & Fish, 1996). A reduction in the salinity regime may cause a greater number of *Elminius modestus* to be present. However, this is unlikely to cause a significant negative impact as they fill the same functional niche. *Mytillus edulis* is considered to be tolerant of a wide range of salinities (Holt *et al*., 1998). *Littorina littorea*, *Littorina saxatilis* and *Carcinus maenus* are mobile species and have the ability to move to suitable conditions on the shore.

Sensitivity assessment. A decrease in salinity for this biotope would create a reduced salinity regime. The species within this biotope including the characterizing species would be able to withstand these reductions in salinities, however there may be reductions in the reproductive success and growth rates. Both the resistance and resilience of this biotope is given as ‘Medium’. The sensitivity of this biotope to the pressure at this benchmark is ‘Medium’.

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

Water motion is a key determinant of marine macroalgal ecology, influencing physiological rates and community structure (Hurd, 2000). Higher water flow rates increase mechanical stress on macroalgae by increasing drag. Fucoids are highly flexible but not physically robust and an increase in water flow could cause mechanical damage, breaking fronds or even dislodging whole algae from the substratum. Fucoids are however highly flexible and are able to re-orientate their position in the water column to become more streamlined. This ability allows fucoids to reduce the relative velocity between algae and the surrounding water, thereby reducing drag and lift (Denny *et al*., 1998). Fucoids are permanently attached to the substratum and would not be able to re-attach if removed. Organisms living on the fronds and holdfasts will be washed away with the algae whereas free-living community components could find new habitat in surrounding areas. Wave exposure has been shown to limit size of fucoids (Blanchette, 1997) as smaller individuals create less resistance to water movement, it is likely that water flow exerts a very similar pressure on fucoids.

This biotope can be found in tidal currents ranging from 3 m/s to those which are considered negligible (Connor *et al*., 2004). The ability of this biotope to be found within conditions with minimal tidal flow suggests that there is unlikely to be a negative impact of a decrease in the mean spring bed flow velocity of 0.2m/s in flow rate. Yet some water flow is required to supply vital nutrients and gases and to remove waste products. If the reduction meant that water flow stopped all together then the biotope may suffer negative impacts, due to stagnant conditions.

An increase in this pressure at the bench mark rate within a biotope which is already found at the top of the tolerance for water flows may be negatively affected. The highest water flow that would be created within this biotope taking into consideration the level of the benchmark is 3.2 m/s. This flow rate is not high enough to remove the two characterizing species.

Fucus vesiculosus individuals of 10 cm or larger have been recorded to be completely removed at 7-8 m/s (Jonsson *et al*., 2006). A considerably greater flow rate than what is experienced at the extreme end of this benchmark within this biotope. Flow rates at which adult *Ascophyllum nodosum* are removed are not known. However, Thomson & Wernberg (2005) provide strong evidence that with an increase in thallus size there is a increase in the break force required to remove algae. Consequently the force required to remove *Ascophyllum nodosum* from a shore is likely to be comparable to that of *Fucus vesiculosus.* In addition there are *Ascophyllum nodosum* biotopes which are found in areas with tidal streams in excess of 6 knots, compared to the 3 knot maximum found within this biotope. This evidence suggests that the characterizing macroalgae populations are unlikely to be torn from the substrate at the level of this benchmark. The risk of dislodgement would only be greater where algae are attached to pebbles instead of bedrock. Indeed if sediment type is small and the substratum is less stable, individuals may eventually reach a critical size when the drag force exceeds gravity and the plant will be moved together with its substratum (Malm, 1999). This risk is increased during the late phase of reproduction for *Fucus vesiculosus* when its receptacles become swollen and gas-filled increasing the uplifting force of water flow (Isaeus, 2004).

Propagule dispersal, fertilization, settlement, and recruitment are also influenced by water movement (Pearson & Brawley, 1996). An increase in water flow could have negative impacts on the reproductive success of *Ascophyllum nodosum.* Experiments on the effect of wave action on *Ascophyllum nodosum* showed that a low-velocity wave can remove 99% of 15 minute old zygotes from experimental tiles Vadas *et al.* (1990). Further investigation with the use of refuges found that 75-90% of zygotes as old as four hours could be removed by a single wave. Current speeds of over 20 cm/s make attachment success of *Ascophyllum nodosum* very poor (Vadas *et al*., 1992). These studies show the need for periods of calm conditions for successful recruitment for *Ascophyllum nodosum.* An increase in the mean water flow will reduce the time during which attachment is possible. In addition, greater water flow can increase scour through increased sediment movement. Small life stages of macroalgae are likely to be affected by removing new recruits from the substratum and hence reducing successful recruitment (Devinny & Volse, 1978) (see ‘siltation’ pressures). Changes in water motion can thus strongly influence local distribution patterns of *Fucus* spp. (Ladah *et al*., 2008).

On the other hand, 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).

Sensitivity assessment. A decrease in water flow could reduce the removal of waste products and the return of nutrients and gases. For this reason biotopes which experience low levels of water flow naturally may be more affected than those found in areas with more water movement. However, this is unlikely to cause any mass mortality, more a decrease in the health of the biotope.

An increase in the level of water flow would be more likely to affect the reproductive and recruitment success of the species. Again this would not cause a mass mortality, but more a decrease in the health of the biotope. The resistance and resilience have been assessed as 'High'. This gives the biotope an overall sensitivity of 'Not Sensitive'.

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

Fucus vesiculosus can tolerate desiccation until the water content is reduced to ~ 30%. If desiccation occurs beyond this level, irreversible damage occurs. Individuals at the top of the shore probably live at the upper limit of their physiological tolerance and therefore are likely to be unable to tolerate increased desiccation and would be displaced by more physiologically tolerant species. Tolerance to this pressure is likely to vary on a geographical scale. Gylle *et al.* (2009) found that *Fucus vesiculosus* populations naturally occurring in fully saline conditions had a higher emersion stress tolerance compared to brackish populations.

Early life history stages are more susceptible to this pressure compared to adults (Henry & Van Alstyne, 2004). 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 adjacent bare rock was close to 0% during exposure to aerial conditions. The *Fucus* canopy is also likely to protect other underlying species to a great extent. Mortalities of other components of the community will however occur if the canopy is removed (see 'abrasion' pressure).

Within the British Isles populations of *Ascophyllum nodosum* can suffer from bleaching and consequent mortality during exceptionally hot weather (Schonbeck & Norton, 1978, Hawkins & Hartnoll, 1985, Norton, 1985). However, these mortality events do not occur every year and tend to occur when the effects of unusually hot conditions combine with periods of rapid change, which do not allow for macroalgae to acclimate (Raffielli & Hawkins, 1996).

Stengel & Dring (1997) reported that growth rates in *Ascophyllum nodosum* decreased with height on the shore, correlating with an increase in environmental severity. *Ascophyllum nodosum* productivity is affected by desiccation when water loss exceeds 50% (Brinkhuis *et al.*, 1976). Higher temperatures can increase the rate of desiccation and consequently lead to a loss of productivity, and eventually mortality (Keser *et al.*, 1981).

When Stengel & Dring (1997) transplanted *Ascophyllum nodosum* from the lower shore to the upper shore, 80% of the transplants died within 3 months. In contrast, 100% of the individuals from the upper shore transplanted to the lower shore survived, as did all of the controls. The plants which survived transplantation to the upper shore acclimated to the conditions on the upper shore, yet their survival was determined by thallus morphology a predetermined genetic attribute which may be fixed (Stengel & Dring, 1997). Choi & Norton (2005) also carried out transplantation experiments and found that the growth rates of *Ascophyllum nodousm* decreased dramatically from the lower shore to the upper shore.

The southern and northern range limits of a number of intertidal macroalgae fall within Portugal. Lima *et al.* (2007) mapped the re-adjustment of 129 macroalgal ranges in relation to the change in air and sea temperatures observed within the north-eastern Atlantic over the past 50 years. Significant differences in distributions of algae were found, yet there were disparity in the level of change found in the ranges of those of warm and cold adapted species. The species that were at the northern limit of their range in Portugal showed a greater change in distribution than the cold adapted species. Roughly half of the cold adapted species, including *Ascophyllum nodosum*, showed no significant change in their distribution. Lima *et al.* (2007) suggested that the cold adapted species had greater tolerance to adverse conditions for longer periods of time than the warm adapted species.

Information regarding the effect of changes in the level of exposure on *Ascophyllum nodosum* germlings is not available. Germlings will be protected from desiccation stresses to a certain extent because of the protection provided to them by the fucoid canopy. Increases in temperature will be one of the effects changes in exposure will have on germlings. For further information refer to temperature pressure. Dense aggregations of algae can reduce the effect of more severe physical conditions such as those experienced with greater levels of exposure. Clumping enables organisms to retain moisture and reduce heat stress (Scrosati & DeWreede, 1998, Stafford & Davies, 2005

Sensitivity assessment. Desiccation and the associated osmotic stress, especially when combined with high temperatures can cause mortalities (Pearson *et al*., 2009). The sensitivity of the characterizing species to emersion pressure will depend on the health and demography of individual populations, with germlings being most vulnerable life stage to this pressure.

Both *Fucus vesiculosus* and *Ascophyllum nodosum* have a level of resistance to an increase in emersion. However, at the level of the benchmark there is likely to be a change in biotope, with the top of the biotope being most sensitive to change as it is already at the upper tolerance limits. The change in this pressure at the benchmark is likely to see all of the biotopes on the shore shifting downwards. *Fucus vesiculosus* can repopulate an area faster than *Ascophyllum nodosum*. *Ascophyllum nodosum* can take as many as twelve years to recover, with return of ecosystem functioning taking considerably longer. Resistance of this biotope to pressure at the stated benchmark has been assessed as ‘Low’ and resilience is assessed as ‘Low’. Overall the biotope has a ‘High’ sensitivity to changes in emergence regime at the pressure benchmark.

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

An increase in wave exposure generally leads to a decrease in macroalgae abundance and size (Lewis, 1961, Stephenson & Stephenson, 1972, Hawkins *et al*., 1992, Jonsson *et al*., 2006). Fucoids are highly flexible but not physically robust and an increase in wave exposure can cause mechanical damage, breaking fronds or even dislodging whole algae from the substratum. Fucoids are permanently attached to the substratum and would not be able to re-attach if removed. Organisms living on the fronds and holdfasts will be washed away with the algae whereas free-living community components could find new habitat in surrounding areas. Wave exposure has been shown to limit size of fucoids (Blanchette, 1997) as smaller individuals create less resistance to waves. As exposure to waves increases the fucoid population will become dominated by small juvenile algae, and dwarf forms of macroalgaes which are more resistant to strong wave action. An increase in wave action beyond the tolerance of these fucoid species leads to a further increase in the abundance of robust fucoids, such as *Fucus spiroalis* f. *nana* and red seaweeds, such as *Corallina officinalis* (Connor *et al*,. 2004).

A recent study investigated the combined impacts of wave action and grazing on macroalgae distribution (Jonsson *et al*., 2006). It suggested that recruitment and survival of juvenile *Fucus vesiculosus* is controlled indirectly by wave exposure, through higher limpet densities at exposed locations (Jonsson *et al*,, 2006). *Fucus vesiculosus* have shown to adapt their morphology to wave exposure to help cope with the stress. For instance, Bäck (1993) observed shorter individuals with narrow fronds on exposed shores lacking bladders to reduce drag. An alternative coping strategy for wave induced forces is thallus toughening. In the north and the Baltic Sea, thalli from exposed *Fucus vesiculosus* were 30% more resistant to tear and breakage compared to those from more sheltered sites (Nietsch, 2009). Furthermore, *Fucus vesiculosus* is able to regenerate from holdfasts (Malm & Kautsky, 2003). *Fucus vesiculosus* can grow in its canopy forming state in biotopes which are found in moderately exposed conditions (Connor *et al.*, 2004). Moderately exposed conditions are considerably higher than what is experienced within this biotope, suggesting that *Fucus vesiculosus* would not be affected by an increase in the pressure at the benchmark within this biotope.

Ascophyllum nodosum cannot resist very heavy wave action so exposure to wave action is an important factor controlling the distribution of the species, and therefore this biotope. This biotope is found in very sheltered to extremely sheltered conditions. Propagule dispersal, fertilization, settlement, and recruitment are also influenced by water movement (Pearson & Brawley, 1996). An increase in water flow due to wave exposure could have negative impacts on the reproductive success of *Ascophyllum nodosum*. Experiments on the effect of wave action on *Ascophyllum nodosum* showed that a low-velocity wave can remove 99% of 15 minute old zygotes from experimental tiles Vadas *et al.* (1990). Further investigation with the use of refuges found that 75-90% of zygotes as old as four hours could be removed by a single wave. Current speeds over 20 cm/s make attachment success of *Ascophyllum nodosum* very poor (Vadas *et al.*, 1992). These studies show the need for periods of calm conditions for successful recruitment for *Ascophyllum nodosum*. An increase in the mean wave exposure will reduce the time during which attachment is possible. In addition, greater wave action can increase scour through increased sediment movement. Small life stages of macroalgae are likely to be affected by removing new recruits from the substratum and hence reducing successful recruitment (Devinny & Volse, 1978) (see 'siltation' pressures). However dense canopies of *Ascophyllum nodosum* can develop in sheltered conditions, an exposure category above that which is found within this biotope (Connor *et al.*, 2004). This suggests that an increase in this pressure at the benchmark would not have a negative impact on *Ascophyllum nodosum* within this biotope

An increase in this pressure at the level of the benchmark within this biotope is highly unlikely to cause a decrease in any of the associated community within this biotope. All of the species can all be found in other biotopes which have greater wave exposures than sheltered (Connor *et al.*, 2004).

Sensitivity assessment. A change in wave exposure at the level of the benchmark within this biotope is highly unlikely to have negative impacts. Therefore the resistance and resilience have been assessed as 'High', which results in a sensitivity assessment of 'Not Sensitive'.

Chemical Pressures

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

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

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

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

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

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

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

No evidence.

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

This pressure is **Not assessed**.

De-oxygenation	Medium Q: Medium A: Medium C: Medium	High Q: High A: Medium C: Medium	Low Q: Medium A: Medium C: Medium

Reduced oxygen concentrations have been shown to inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al*., 2012). Reduced oxygen levels are likely to inhibit respiration whilst immersed, but it is unlikely to cause a loss of the macroalgae population directly. This biotope is found in a mid-eulittoral position and consequently a proportion of time will be spent in air where oxygen is not limited. As long as certain physical conditions are not exceeded, respiration and photosynthesis will be able to continue.

Although the macroalgae species within this biotope may not be negatively affected some of the associated fauna may be lost, causing a reduction in species richness. 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. Mobile species will be able to relocated to more optimal conditions, whereas immobiles species such as barnacles are likely to be put under more stress by de-oxygenation. Complete smothering caused by the *Torrey Canyon* oil spill appeared to have little impact on barnacle species; A few *Semibalanus balanoides* died, yet *Chthamalus montagui* seemed unaffected (Smith, 1968). *Semibalanus balanoides* can respire anaerobically, so they can tolerate some reduction in oxygen concentration (Newell, 1979). When placed in wet nitrogen, where oxygen stress is maximal and desiccation stress is low, *Semibalanus balanoides* have a mean survival time of 5 days (Barnes *et al*., 1963).

The very sheltered to extremely sheltered and the moderately strong to negligible tidal flows which are characteristic of this biotope means that 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 vesiculosus* and *Ascophyllum nodosum* would not be negatively affected by a decrease in oxygen within the water column for at the benchmark level of this pressure. However, some of the associated faunal community within this biotope may be negatively affected. Mobile species such as littorinids and the crab *Carcinus maenas* would relocated to conditions that were less physiologically taxing, and would be able to return when the pressure abated. Those immobile species such as the barnacles *Austrominius modestus* and *Semibalanus balanoides* may experience some mortality. However, barnacles can completely recolonize within three years (Bennell, 1981). A reduction in oxygen levels at the benchmark for this pressure would result in mortalities. Resistance is assessed as 'Medium'. Due to the speed of recovery resilience is assessed as 'High', giving the biotope a sensitivity score of 'Low'.

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

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

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

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).

White *et al.*, (2011) investigated the effects of nutrient effluent from land based finfish farms on the morphologies of *Ascophyllum nodosum* in the vicinity of the outfall pipes. It was estimated that the nitrogen effluent from the farm was 1500kg/year. The background levels of nitrite at the test site were 300 µM, in comparison the ambient nitrite levels in southwest Nova Scotia are 3 µM (White *et al.*, 2011). *Ascphyllum nodosum* at the test sites were found to be younger than those at the control sites, but significantly larger. This experiment suggested that nutrient effluent could have positive impacts on *Ascophyllum nodosum*. Yet it must be noted that the effect of the effluent on the rest of the biological community was not studied.

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

Sensitivity assessment. 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. If the biotope is well established and in a healthy state the biotope could persist. However, the biotope is ‘Not Sensitive’ at the pressure benchmark that assumes compliance with good status as defined by the WFD.

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 were ‘remarkably consistent’ between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995; Archambault *et al.*, 2001; Arévalo *et al.*, 2007; Diez *et al.*, 2003; Littler & Murray, 1975).

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 fucoid 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). Bellgrove *et al*. (2010) found that coralline turfs out-competed fucoids at a site associated with organic enrichment caused by an ocean sewage outfall.

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

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. Due to the negative impacts that can be experienced with the introduction of excess organic carbon both resistance and resilience have 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 rock substratum, a change towards a sedimentary or soft rock substratum would lead to the direct loss of suitable attachment area for macroalgae and other epibiota. This change in substratum would result in the loss of the characterizing species *Fucus vesiculosus* and *Ascophyllum nodosum* along with other species found within the community of this biotope. Resistance is assessed as 'None'. As this pressure represents a permanent change, recovery is impossible as the suitable substratum for fucoids is lacking. Consequently, resilience is assessed as

'Very low'. The habitat, therefore, scores a 'High' sensitivity. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant

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	Low Q: High A: Medium C: Medium	High 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* (Fletcher & Frid, 1996). This biotope is found in the mid intertidal shore. An area easily accessible by humans especially at low tide. Individual microalgae's are flexible but not physically robust. Fucoids are intolerant of abrasion from human trampling, which has been shown to reduce the cover of seaweeds on a shore (Holt *et al.*, 1997).

Brosnan (1993) investigated the effect of trampling on a number of algal species, including *Fucus vesiculosus*, 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, 1996). This reduction in the complexity of the algae community, in turn, reduced the microhabitat available for epiphytic species. Trampling pressure can thus result in an increase in the area of bare rock on the shore (Hill *et al.*, 1998). Chronic trampling can affect community structure with shores becoming dominated by algal turf or crusts (Tyler-Walters, 2005). Pinn & Rodgers (2005) compared the biological communities found on two intertidal rocky shore ledges in Dorset. They found that the ledge which had a higher number of visitors had few branching algal species, including fucoids, but had greater abundances of crustose and ephemeral species (Pinn & Rodgers, 2005). The densities of fucoids were recorded from the intertidal rocky shore at Wembury, Devon in 1930 (Colman, 1933) and 1973 (Boalch *et al.*, 1974). Boalch *et al.* (1974) found a reduction in fucoids on the shore at Wembury and that the average frond length of *Ascophyllum nodosum and Fucus vesiculosus* was smaller.

Fucus vesiculosus is able to generate vegetative regrowth in response to wounding from physical disturbance. McCook & Chapman (1992) experimentally tested the recovery of damaged *Fucus vesiculosus*. The study found that vegetative sprouting of *Fucus vesiculosus* holdfasts made a significant addition to the regrowth of the canopy, even when holdfasts were cut to less than 2 mm tissue thickness. Four months after cutting, sprouts ranged from microscopic buds to shoots about 10 cm long with mature shoots widespread after 12 months. Vegetative regrowth in response to wounding has been suggested as an important mean of recovery from population losses (McLachan & Chen, 1972).

Ascophyllum nodosum seems to be particularly intolerant of damage from trampling (Flavell, unpublished; cited in Holt *et al*., 1997). It is also likely to be removed if shores are mechanically cleaned following oil spills. Araujo *et al.* (2009) found that trampling negatively affected both *Ascophyllum nodosum* and *Fucus vesiculosus* abundances and reduced understorey species while promoting the colonization by ephemeral green algae. However, within a year of the disturbance event, *Fucus vesiculosus* recovered and greatly increased in cover becoming the dominant canopy forming species, replacing a pre-disturbance *Ascophyllum nodosum* community. The replacement of *Ascophyllum nodosum* with *Fucus vesiculosus* may have been due to the poor recovery rate of *Ascophyllum nodosum*. The increase in abundance suggests the competitive superiority of *Fucus vesiculosus* individuals in occupying newly available space in the disturbed patches. Similar results were found by Cervin *et al*. (2005) and Araujo *et al*. (2012) with *Fucus vesiculosus* outcompeting *Ascophyllum nodosum* after small-scale disturbances.

Rita *et al*., (2012) also undertook experiments on the effect of trampling on *Ascophyllum nodosum* and its associated communities. It was concluded that trampling caused significant damage to both the macroalgae and the understory communities, which had not recovered within five years of the initial experiment.

Sensitivity assessment. Abrasion of the substratum will cause a reduction in the abundances of both characterizing species, as well as other species found in the associated community. Therefore the resistance is ‘Low’. Experiments undertaken on the trampling effects on *Ascophyllum nodosum* have shown that for the community to return to its pre-experimental state can take in excess of 10 years, consequently, the resilience is assessed as ‘Low’, giving a sensitivity of ‘High’.

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

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

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

Light is an essential resource for all photoautotrophic organisms and a change in turbidity would affect light availability to photosynthetic organisms during immersion which could result in reduced biomass of plants. Changes in the suspended sediment load can change the levels of scour and alter the abundances of certain species. Greater levels of suspended particulate matter may also increase the amount of material which is falling out of suspension, which could consequently smother organisms (see siltation pressures).

An increase in turbidity would alter the light available for photosynthesis during immersion. The shallow water depth within this biotope means that although light attenuation will be greater, the change in turbidity at this pressure benchmark will still allow light to penetrate to the depth at which the algae are found. *Ascophyllum nodosum* will also be able to continue to photosynthesize at low tide when the plants are emersed, as long as the plant has a sufficiently high water content and so (Beer & Kautsky, 1992).

The distribution of *Fucus vesiculosus* along a depth gradient strongly correlates with light penetration. In areas with low sedimentation *Fucus vesiculosus* can survive down to 9-10 m depth (Eriksson & Bergstrom, 2005). Changes in suspended solids affecting water clarity will have a direct impact on the photosynthesising capabilities of *Fucus vesiculosus.* Irradiance below light compensation point of photosynthetic species can compromise carbon accumulation (Middelboe *et al*., 2006). 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. A decrease in light penetration in the Kiel Fjord caused by an increase in phytoplankton density and shading from filamentous algae has caused an upwards shift of the lower depth limit of *Fucus vesiculosus* (Rohde *et al*., 2008). A decrease in suspended sediment is unlikely to have a negative impact on this species due to it being a primary producer.

Fucus vesiculosus is more tolerant of scour than *Ascophyllum nodosum*. When Daly & Mathieson (1977) compared the impacts of scour on macroalgae on two intertidal rocky shores they found that *Fucus vesiculosus* was present on the sand scoured shore where *Ascophyllum nodosum* was entirely absent. Lewis (1964) (taken from Daly & Mathieson, 1977) also noted that *Ascophyllum nodosum* had a lower tolerance to scour than *Fucus vesiculosus* . *Fucus vesiculosus* was also observed to recover faster from damage caused by scour because it was able to regenerate from holdfasts within the year (Daly & Mathieson, 1977).

Daly & Mathieson (1977) found that *Ascophyllum nodosum* was completely absent from an intertidal rocky shore which was subject to a high level of scour from sand movement. The lack of *Ascophyllum nodosum* from this shore was particularly conspicuous due to the high abundance of the species on a nearby rocky shore with very similar conditions, except for the level of suspended sediment. *Ascophyllum nodosum* is not likely to be directly intolerant of a decrease in suspended sediment because the species is a primary producer.

Scour caused by increased sediment in suspension can cause mortality to many of the other species found within this biotope. For example, Daly & Mathieson (1977) found that *Semibalanus balanoides* could be totally removed from a shore if scour is severe enough. A reduction in light levels due to an increase in the level of suspended sediment will not have a negative impact on the fauna within this biotope, and it is unlikely to have a significant negative impact on the other flora species, due to the intertidal nature of the biotope. An increase in levels of suspended sediment could be beneficial to filter feeding organisms.

Scour caused by increased sediment in suspension can cause mortality to many of the other species found within this biotope. For example Daly & Mathieson, (1977) found that both *Semibalanus balanoides* and *Mytilus edulis* could be totally removed from a shore if scour is severe enough. A reduction in light levels due to an increase in the level of suspended sediment will not have a negative impact on the fauna within this biotope, and it is unlikely to have a significant negative impact on the other flora species, due to the intertidal nature of the biotope.

Sensitivity assessment. This biotope is found on the mid intertidal shore and consequently is subject to long periods of emersion during which time macroalgae can continue to photosynthesize as long as plants have a sufficiently high water content. Therefore, photosynthesis and consequently growth will not be greatly affected. The levels of water movement within this biotope, through water flow and wave exposure, are unlikely to cause any significant damage through scour. Consequently, the resistance and resilience of this biotope have 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: Medium A: Medium C: Medium	Medium Q: High A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium

A discrete event where sediment inundates this biotope to 5cm will have very different effects on the characterizing species and the associated community depending on the state of the tide. High tide will mean that both of the characterizing species will be vertical in the water column, meaning only a small proportion of the stipe and holdfast will be smothered, leaving the fronds sediment free, and able to continue photosynthesis. In contrast, if the tide is out then fronds of the characterizing fucoid canopy will be flat on the substratum and will be smothered by the sediment deposit. The low water flow and wave sheltered position on this biotope will mean that the sediment will not be removed from the shore quickly. Smothering will prevent photosynthesis resulting in reduced growth and eventually death.

However, germlings are likely to be smothered and killed in both scenarios and are inherently most susceptible to this pressure. Indeed early life stages are smaller in size than adults and are thus most vulnerable to this pressure as even a small load of added sediment will lead to the complete burial. Sediment deposition can reduce macroalgal recruitment by (1) reducing the amount of substratum available for attachment of propagules; (2) scour, removing attached juveniles and (3) burial, altering the light and/or the chemical 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. Eriksson & Johansson (2003) found that sedimentation had a significant negative effect on the recruitment success of *Fucus vesiculosus*. Even fine sediment fractions can reduce the successful attachment of fucoids by as much as 90% (Schiel & Foster, 2006).

Ascophyllum nodosum is intolerant of sediments as shown by the shore comparisons undertaken by Daly & Mathieson (1977). Daly & Mathieson (1977) compared two rocky shores which were similar except for the level of sediment movement experienced on the shore. The shore with more sediment movement was devoid of *Ascophyllum nodosum*. In contrast, *Fucus vesiculosus* could be found on both shores. It was suggested that the ability of *Fucus vesiculosus* to be found on the shore affected by sedimentation was due to its ability to regenerate from its holdfast.

Smothering will cause direct mortalities in the associated community, notably of the filter feeding sessile organisms unable to clear their feeding appendages or relocate. Airoldi & Hawkins (2007) found that *Patella vulgata* reduces its feeding activity by 35% with just 1 mm of sediment over the substratum (equivalent to 50 mg/cm^2). At 200 mg/cm^2 mortality occurred. It is possible that 5 cm of sand may create similar mortality events to other grazing organisms, as not only will they be weighted down by sand but food availability will also be restricted.

Sensitivity assessment. *Fucus vesiculosus* adults are relatively tolerant to sediment inundation, and can regenerate from its holdfast. *Ascophyllum nodosum* adults are sediment intolerant, and germlings of both species are intolerant of even small levels of sediment. Many of the smaller species found within the associated community will be totally smothered by 5 cm. Examples of this biotope which are in sheltered or very sheltered conditions sediment will be retained for longer, allowing greater negative effects to occur. Resistance and resilience have both been assessed as 'Medium'. Overall the biotope has a 'Medium' sensitivity to smothering at the level of the benchmark.

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

Several studies found that increasing the vertical sediment burden negatively impact fucoids survival and associated communities. At the level of the benchmark (30 cm of fine material added to the seabed in a single event) smothering is likely to result in mortalities of understorey algae, invertebrate grazers and young (germling) fucoids. Resistance is assessed as 'Low' as all individuals exposed to siltation at the benchmark level are predicted to die. Once conditions return to normal, recovery will be enabled by vegetative growth from remaining *Fucus* tissue, resulting in a 'Medium' resilience. Overall the biotope has a 'Medium' sensitivity to siltation at the pressure benchmark.

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

Not assessed.

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

Not evidence.

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

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

Introduction of light or shading	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Increased levels of diffuse irradiation correlate with increased growth in macroalgae (Aguilera *et al.*, 1999). Levels of diffuse irradiation increase in summer, and with a decrease in latitude. As *Fucus vesiculosus* and *Ascophyllum nodosum* are found in the middle its natural range in the British Isles an increase in the level of diffuse irradiation will not cause a negative impact on the species or the biotope. However, 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

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. Therefore this pressure is considered 'Not Relevant' for this biotope.

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 to most receptors.

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

Thompson & Schiel (2012) found that native fucoids show high resistance to invasions by the Japanese kelp *Undaria pinnatifida*. However cover of *Fucus vesiculosus* was inversely correlated with the cover of the invasive *Sargassum muticum* indicating competitive interaction between the two species (Stæhr *et al*., 2000). Stæhr *et al*. (2000) determined that the invasion of *Sargassum muticum* could affect local algal communities through competition mainly for light and space.

Gracilaria vermiculophylla is suggested to be one of the most successful marine non-native species (Kim *et al*., 2010; Sfriso *et al*., 2010; taken from Thomsen *et al*., 2013). This species invades wave sheltered, shallow water areas, and have been found in biotopes naturally dominated by fucoid canopies (Weinberger *et al*., 2008). Hammann *et al*. (2013) found that in the Baltic Sea *Gracilaria vermiculophylla* could impact *Fucus vesiculosus* through direct competition for resourses, 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 fucoid biotopes, and could become relevant to this specific biotope.

Sensitivity assessment. Fucoid species have been negatively affected by both the direct and indirect consequences of INNS being present. However, no evidence can be found on the impacts of INNS on *Fucus vesiculosus* and *Ascophyllum nodosum* within this biotope. For this reason the effect of this pressure has been given as ‘No Evidence’. Literature for this pressure should be revisited.

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

No evidence.

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

Seaweeds have been collected from the middle of the 16th century for the iodine industry. Modern day industrial uses for seaweed are extensive and include fertilizer, animal feed, alginate extracts (Phillipi *et al*., 2014), water treatment, and human food and health supplements (Bixler & Porse, 2010). The characteristic fucoid algae within this biotope are commercially collected. These commercial harvests remove seaweed canopies which 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 the macroalgae canopy 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 (Stagnol *et al*., 2013). Bertness *et al*. (1999) found that the presence of an *Ascophyllum nodosum* canopy reduced maximum daily rock temperatures by 5-10 °C. It was also reported that water loss via evaporation was an order of magnitude less than that in areas where the fucoid canopy had been removed (Bertness *et al*., 1999).

Stagnol *et al*. (2013) found that suspension feeders were the most affected by the canopy removal as canopy-forming algae are crucial habitats for these species. Other studies confirm that loss of canopy had both short and long-term consequences for benthic community diversity resulting in shifts in community composition and a loss of ecosystem functioning such as primary productivity (Lilley & Schiel, 2006; Gollety *et al*., 2008).

Studies on the effects of commercial harvesting on the faunal communities associated with *Ascophyllum nodosum* have found that removing this key species can reduce abundances of epifauna found on the un-harvested biomass (Jarvis & Seed, 1996, Johnson & Scheibling, 1987; taken from Phillipi *et al*., 2014). Changes *Ascophyllum nodosum* have also been found to affect the large, mobile fauna such as crabs or grazing gastropods (Bertness *et al*., 1999; Fegley, 2001; Jenkins *et al*., 1999, 2004, Phillipi *et al*., 2014).

However, Phillipi *et al*. (2014) replicated commercial harvesting techniques in Maine, USA where *Ascophyllum nodosum* fronds were removed 40.6 cm from the holdfast and the lowest lateral branch must remain with the holdfast (DMR, 2009). The experiment looked specifically at the effect of canopy reduction on infaunal species living within the soft sediments within intertidal rocky shores where *Ascophyllum nodosum* was present. The experiment found that invertebrate species found living on and within sediments were not negatively affected by the harvesting activity (Phillipi *et al.*, 2014).

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 vesiculosus* and *Ascophyllum nodosum* canopy will significantly change the community composition of the biotope. The quantity of biomass removed from the shore and the regularity of removal will all affect how quickly the biotope will be able to recover. *Fucus vesiculosus* and *Ascophyllum nodosum* have a ‘Low’ resistance to removal as both of them are easy to locate and have no escape strategy. Resilience is ‘Low’, however, recovery will only be able to start when the pressure is removed from the shore i.e. harvesting is no longer occurring. A sensitivity of ‘High’ is recorded.

Removal of non-target species	Medium Q: Medium A: Medium C: Medium	Medium Q: High A: Medium 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 *Ascophyllum nodosum* and *Fucus vesiculosus* create a dominant turf within this biotope. The dominance of these characterizing species means they could easily be incidentally removed from this biotope as by-catch when other species are being targeted. 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 ‘none’ 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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