Ascophyllum nodosum on full salinity mid eulittoral rock

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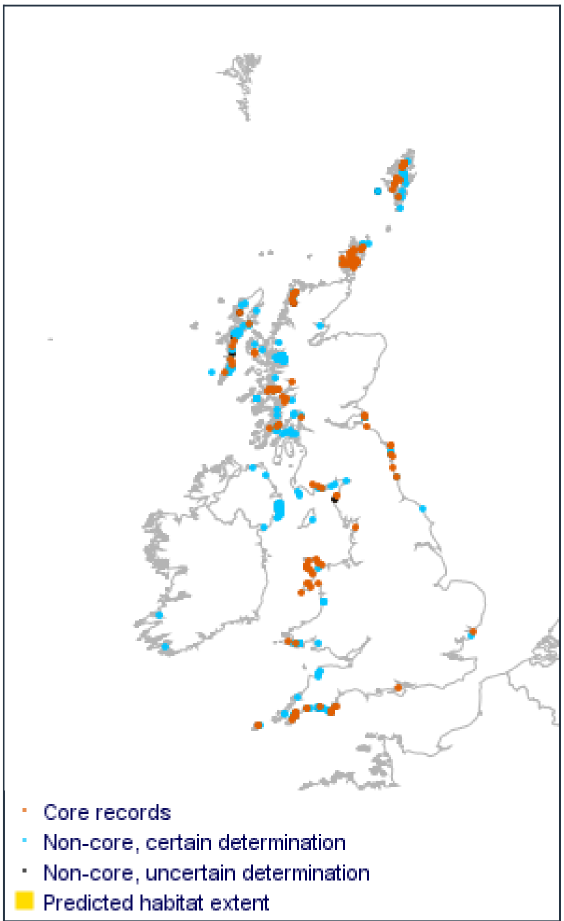
Ascophyllum nodosum **on full salinity mid eulittoral rock**
Photographer: Keith Hiscock



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

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

Summary

UK and Ireland classification

EUNIS 2008	A1.3141	*Ascophyllum nodosum* on full salinity mid eulittoral rock
JNCC 2015	LR.LLR.F.Asc.FS	*Ascophyllum nodosum* on full salinity mid eulittoral rock
JNCC 2004	LR.LLR.F.Asc.FS	*Ascophyllum nodosum* on full salinity mid eulittoral rock
1997 Biotope	LR.SLR.F.Asc.Asc	*Ascophyllum nodosum* on full salinity mid eulittoral rock

Description

Bedrock, or stable boulders and cobbles, in the mid-eulittoral zone of sheltered to very sheltered shores, typically in fully marine or near fully marine conditions, are characterized by a dense canopy of *Ascophyllum nodosum*. *Fucus vesiculosus* also occurs and in some places may co-dominate the canopy. Such mixed canopies occur when clearings are formed in the *Ascophyllum*, since *F. vesiculosus* is able to colonise such clearings more rapidly. *Ascophyllum* (which may live for up to 25 years) will, however, eventually out-compete any *F. vesiculosus*. Such changes in the overlying canopy have little effect on the under-storey species. Beneath the canopy, filamentous and foliose red algae, including *Mastocarpus stellatus* and *Chondrus crispus*, and the green alga *Cladophora rupestris*, occur in moderate to low densities. The *Ascophyllum* is generally epiphytised by *Polysiphonia lanosa* (compare with Asc.VS). Very steep and vertical surfaces are often characterized by barnacles and limpets (BPat.Sem), but by small fucoids in areas of extreme shelter. Large numbers of the winkle *Littorina obtusata* may be present. This biotope usually lies between the *Fucus spiralis* (Fspi) and *Fucus serratus* (Fser) zones, although on some shores a narrow zone of *Fucus vesiculosus* (Fves) may occur immediately above the *Ascophyllum*. With increasing wave exposure the *Ascophyllum* canopy is replaced by *F. vesiculosus* (Fves). Asc.Asc may also occur on moderately exposed shores, where there is localised shelter.

Depth range

Mid shore

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The community within this biotope are characterized by a dense canopy of *Ascophyllum nodosum*. The fucoids *Fucus vesiculosus* and *Fucus serratus* are also found within this biotope. The red seaweed *Polysiphonia lanosa* is a frequent epiphyte on *Ascophyllum nodosum*. The barnacle species *Semibalanus balanoides* is found on the rock surfaces beneath the canopy, along with the limpet species *Patella vulgata*. Both of these species are important in the structuring of the biological community on rocky intertidal ecosystems (Hawkins, 1983). A number of littorinids are found within this biotope and are important grazers. The crab *Carcinus maenas* and the dog whelk *Nucella lapillus* are dominant predators.

Ascophyllum nodosum is the key structuring species of this biotope. This species acts as an ecosystem engineer and the canopy that their fronds create modify habitat conditions. Although *Fucus vesiculosus* is important to this biotope, if this species were missing the biotope would still exist. 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). Therefore, the sensitivity assessment is based on the key structuring species (*Ascophyllum nodosum*), although the sensitivity of other species is addressed where relevant.

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 m^{-2} $years^{-1}$ 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 and 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^{-1} 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. 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 (1959) 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 $^{\circ}$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); 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.

The high levels of water movement within this biotope make it a suitable habitat for a number of filter feeders. Although their presence is mediated by the presence of *Ascophyllum nodosum* the resistance and resilience of these species is important when considering how long it would take for this biotope to return to full ecosystem function. The average life expectancy of *Halichondria panicea* is three years (Fish & Fish, 1996) with individuals reaching sexual maturity within their first year. Wapstra & van Soest (1987) found that oocytes were present in the hermaphroditic *Halichondria panicea* year round. Maturation of these oocytes and the present of embryos were present from May to August when water temperatures increased. New *Halichondria panicea* recruits can become apparent on the shore a year after they were spawned (Vethaak, 1982). *Ascidiella scabra* the sea squirt is a highly fecund species (Lindsay & Thompson, 1930). Age at maturity is thought to be 6 months with a lifespan of 2-5 years. *Semibalanus balanoides* are often quick to colonize available gaps on intertidal rocky shores. Bennell (1981) observed that barnacles that were removed when the surface rock was scraped off in a barge accident at Amlwch, North Wales returned to pre-accident levels within 3 years. Petraitis & Dudgeon (2005) also found that *Semibalanus balanoides* quickly recruited (present a year after and increasing in density) to experimentally cleared areas within the Gulf of Maine, that had previously been dominated by *Ascophyllum nodosum.* However barnacles are gregarious and larvae settle within areas where adults are present (Knight-Jones & Stevenson, 1950). Re-colonization of *Patella vulgata* on rocky shores is rapid as seen by the appearance of limpet spat 6 months after the *Torrey Canyon* oil spill reaching peak numbers 4-5 years after the spill. However, although re-colonization was rapid, the alteration to the population structure (size and age class) persisted for about 15 years because of the complex cycles of dominance (see below) involving limpets, barnacles and algae (Hawkins & Southward, 1992, Lewis & Bowman, 1975). The ability of these species to recolonize a habitat after the negative effects of a pressure varies. However *Ascophyllum nodosum* takes the longest to recover and therefore it is this species on which the recovery of this biotope hinges.

Resilience assessment. *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 12 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 15 cm – 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 after a mass mortality event the understory communities and ecosystem functioning of the area can take in excess of 20 years to return (Jenkins *et al.*, 2004).

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 reported to be in excess of twenty years. This biotope has a diverse associated community, some of the species within which can recover relatively quickly, so recovery times scales may vary. In conclusion, if only partial damage is done to the characterizing macroalgae within his biotope then recovery could be quick between two to ten years, giving a resilience of 'Medium'. However if a pressure causes a significant mortality of the characterizing species, *Ascophyllum nodosum,* 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.

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* (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 *Ascophyllum nodosum* is found in the middle of its 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

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.

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. Growth of *Ascophyllum nodosum* has been measured between 2.5 and 35°C with an optimum between 10 and 17°C (Strömgren, 1977). Water temperature is an excellent predictor of gamete release in *Ascophyllum* (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.

A large number of the species found within this biotope are found throughout the British Isles and are not on the edge of their range. Therefore it is unlikely that a decrease in temperature is going to cause significant mortalities. In addition to this those species which are mobile, such as the littorinids, *Nucella lapillus* and *Carcinus maenas* have the opportunity to move away from areas if physical conditions become too harsh. Consequently these species may decrease in abundance.

Sensitivity assessment. The characterizing species, *Ascophyllum nodosum*, is found in the middle of its habitat range in the British Isles. Although the range of this 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 macroalgae. 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 a 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)	Low Q: High A: High C: Medium	Low Q: High A: Medium C: Medium	High Q: High A: Medium C: Medium

Intertidal macroalgae 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 causing hyper saline conditions 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 recorded from fully saline conditions (30 -40 ppt) (Connor *et al.*, 2004). Consequently an increase in salinity could make the conditions hypersaline. Little empirical evidence was found to assess how an increase in salinity at this benchmark would affect *Ascophyllum nodosum.* 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 species associated with this biotope can also be found within rockpools where hypersaline conditions can be found for short periods of time (Newell, 1979). Consequently an increase in salinity within the benchmark of this pressure may not cause negative impacts for a short period of time . *Semibalanus balanoides* can tolerate salinities between 12 and 50 psu; below and above this cirral activity ceases (Foster, 1970). The littorinids, *Nucella lapillus* and *Carcinus maenus* are mobile species and have the ability to move to suitable conditions on the shore.

Sensitivity assessment. This biotope is only found in full saline conditions (30 - 40 ppt) (Connor *et al.*, 2004). Therefore the pressure at this benchmark would create hyper-saline conditions. Although many species within this biotope would be able to cope with a short-term increase in salinity, long-term hypersaline conditions could cause mass mortalities of the biological community within this biotope. Both the resistance and resilience of this biotope to pressure at the stated benchmark has been assessed as 'Low'. Overall the biotope has a 'High' sensitivity to changes in emergence regime at the pressure benchmark.

Salinity decrease (local)	Low Q: High A: High C: Medium	Low Q: High A: Medium C: Medium	High 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 causing hyper saline conditions 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.

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 8psu (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 for short periods of time (Newell, 1979). Consequently a decrease in salinity within the benchmark of this pressure would not cause any significant mortalities. For example, *Semibalanus balanoides* can tolerate salinities between 12 and 50 psu, below and above this cirral activity ceases (Foster, 1970). Both *Ascidiella scabra* and *Halichondria panicea* can be found in habitats with variable salinity and would therefore tolerate a decrease in the salinity within this biotope. The littorinids, *Nucella lapillus* and *Carcinus maenas* are mobile species and have the ability to move to suitable conditions on the shore.

Sensitivity assessment. This biotope is only recorded within fully saline conditions (30 -40 ppt) (Connor *et al*., 2004). A decrease in salinity at the given benchmark could create a variable salinity regime. Consequently the biotope would change to one with a variable salinity regeime. Although there would be a total change in biotope, there would not be mass mortality of either the characterizing species (*Ascophyllum nodosum*) or the rest of the associated community. This is due to the ability of many of the species within this biotope to cope with the salinity reduction at the benchmark pressure. However it is possible that there would be reductions in the reproductive success and growth rates, and consequently the abundances of some species. Both the resistance and resilience of this biotope is given as 'Low'. The sensitivity of this biotope to the pressure at this benchmark is 'High'.

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 1 - 3 knots (0.5 – 1.5 m/s) (Connor *et al*., 2004).

Fucus vesiculosus individuals of 10cm or larger have been recorded to be completely removed at 7-8m/s (Jonsson *et al*., 2006). Flow rates at which adult *Ascophyllum nodosum* are removed are not known. However Thompson & Wernberg (2005) provide strong evidence that with an increase in thallus size there is an 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 due to them both being large macroalgae with similar thallus sizes. The upper limit of the tidal flows within this biotope are >1.5 m/s. An increase in current flow of 0.2 m/s is unlikely to have an impact on many examples of this biotope except for those which are at the upper limit of water flow tolerance.

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^{-1} 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).

Sensitivity assessment. This is not a tidally swept biotope, consequently the abundance of filter feeders and epifauna is not dependent on the high water flow. This biotope is present in negligible water flows therefore a decrease in water flow is unlikely to have an impact. An increase in the level of water flow at the benchmark (0.1-0.2 m/s) is unlikely to have significant effect. Therefore, resistance and resilience have been assessed as 'High'. This gives the biotope an overall sensitivity of 'Not Sensitive' at the benchmark level.

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

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 macroalgaes 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.

Ascophyllum nodosum has 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. *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)	Medium Q: Medium A: Medium C: Medium	Medium Q: High A: Medium C: Medium	Medium Q: Medium 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. *Ascophyllum nodosum* is 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 macroalgae 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 spiralis* f. *nana* and red seaweeds, such as *Corallina officinalis* (Connor *et al*,. 2004).

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 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 20cm s^{-1} 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).

The other characterizing species are found in a range of wave exposures and unlikely to be directly affected. However, loss of the fucoid cover would result in major changes to the associated community, especially attached epifauna and understory algae.

Sensitivity assessment. As this is a very to extremely sheltered biotope a further decrease in wave exposure is unlikely, and not significant given the very strong to strong tidal flow in which the biotope occurs. An increase in wave action, is likely to adversely affect fucoid cover, especially of *Ascophyllum nodosum*. The biotope will probably be lost if wave exposure increase from e.g. sheltered to moderately exposed. It is difficult to qualify a 3-5% change in significant wave height in terms of wave exposure, but the biotope is likely to have at least a 'Medium' resistance to an increase in wave exposure. Therefore, as the resilience is probably 'Medium', sensitivity is also 'Medium'.

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.

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

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

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

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

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

No evidence.

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

This pressure is **Not assessed**.

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

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).

Sensitivity assessment. The characterizing species *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 relocate to conditions that were less physiologically taxing, and would be able to return when the pressure abated. Those immobile species such as the barnacle *Semibalanus balanoides* may experience some mortality. However, barnacles can completely recolonize within three years (Bennell, 1981).

The sheltered to extremely sheltered conditions that are characteristic of this biotope mean 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. However, the biotope occurs in the mid-littoral so that emergence will mitigate the effects of hypoxic surface waters. Therefore, resistance is assessed as ‘High’. Hence, resilience is assessed as ‘High’, and the biotope as 'Not sensitive'.

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

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

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

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 y^{-1}. The background levels of nitrite at the test site were 300 µM. In comparison, the ambient nitrite levels in south-west Nova Scotia are 3 µM (White *et al.*, 2011). *Ascophyllum 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 was 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation, there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

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

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

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

Not relevant.

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. Fucoids are intolerant of abrasion from human trampling, which has been reported to reduce the cover of seaweeds on a shore (Holt *et al.*, 1997; Tyler-Walters & Arnold, 2005).

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* was smaller.

Ascophyllum nodosum seems to be particularly intolerant of damage from trampling (Flavell, unpublished; cited in Holt *et al.*, 1997), as its length means it is more likely that the thallus is 'cut' between a footstep and sharp rock (Boalch *et al.*, 1974, Tyler-Walters & Arnold, 1995). Araujo *et al.* (2009) found that trampling negatively affected both *Ascophyllum nodosum* abundances and reduced understorey species while promoting the colonization by ephemeral green algae. However, within a year of the disturbance event, *Fucus vesiculosus* had become 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 *Ascophyllum nodosum*, 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: Medium A: Medium C: Medium	High Q: High A: Medium C: Medium	Not sensitive Q: Medium 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).

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.

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 level of water movement through wave exposure and tidal streams is unlikely to be high enough 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	Medium	Medium
	Q: Medium A: Medium C: Medium	Q: High A: Medium C: Medium	Q: Medium A: Medium C: Medium

A discrete event where sediment inundates this biotope to 5 cm 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 level of water flow caused by tidal movements and wave exposure within this biotope will mean that the sediment won't 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).

Ascophyllum nodosum is intolerant of sediment movement 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.*

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. *Ascophyllum nodosum* adults are sediment intolerant, and germlings of *Ascophyllum nodosum* 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. The level of water movement within this biotope is not excessive and consequently deposited sediment will persist over a number of tides before it is all entrained and removed. This is likely to cause some damage to the characterizing species and the other associated species. Therefore, resistance and resilience have both been assessed as 'Medium'. Overall the sensitivity of the biotope is assessed as 'Medium' at the level of the benchmark.

Smothering and siltation rate changes (heavy)	Low Q: Medium A: Medium C: Medium	Low Q: High A: Medium C: Medium	High 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. Water movement will remove sediment but within this biotope is it likely to take a number of tidal cycles. Resistance and resilience are 'Low'. Overall the biotope has a 'High' sensitivity to siltation at the pressure benchmark.

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

Not assessed.

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

No evidence.

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

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

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

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

	Resistance	Resilience	Sensitivity
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'.

	Resistance	Resilience	Sensitivity
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

No relevant.

Biological Pressures

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

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

	Resistance	Resilience	Sensitivity
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). 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 *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.

	Resistance	Resilience	Sensitivity
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 *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. *Ascophyllum nodosum* has a 'Low' resistance to removal as it is 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	Low Q: High A: High C: Medium	Low Q: High A: Medium C: Medium	High Q: High A: Medium C: Medium

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

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

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