Porphyra purpurea and *Ulva* spp. on sand-scoured mid or lower eulittoral rock

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***Porphyra purpurea* and *Enteromorpha spp.* on sand-scoured mid or lower eulittoral rock**
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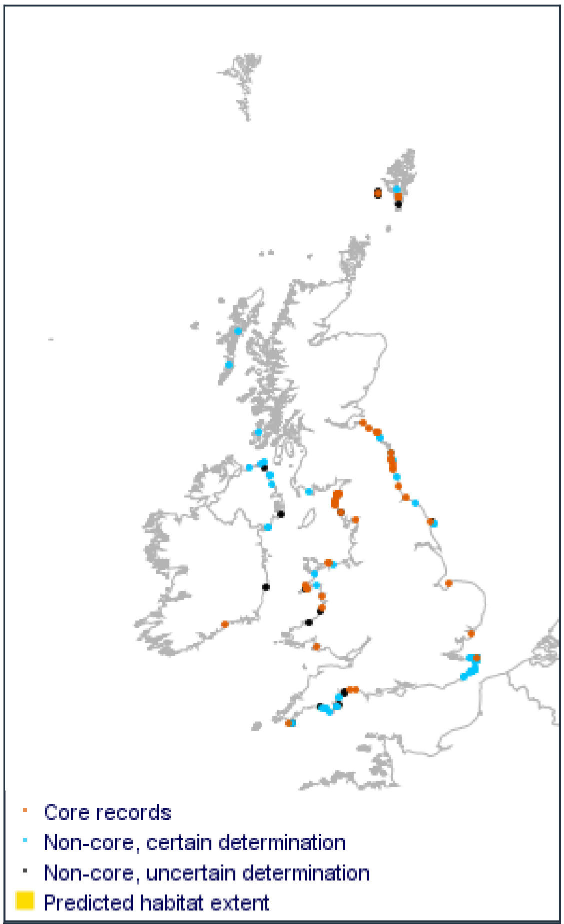

17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Dr Heidi Tillin & Georgina Budd **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A1.452	*Porphyra purpurea* or *Enteromorpha* spp. on sand-scoured mid or lower eulittoral rock
JNCC 2015	LR.FLR.Eph.UlvPor	*Porphyra purpurea* and *Ulva* spp. on sand-scoured mid or lower eulittoral rock
JNCC 2004	LR.FLR.Eph.EntPor	*Porphyra purpurea* and *Enteromorpha spp.* on sand-scoured mid or lower eulittoral rock
1997 Biotope	LR.MLR.Eph.EntPor	*Porphyra purpurea* or *Enteromorpha spp.* on sand-scoured mid or lower eulittoral rock

Description

Exposed and moderately exposed mid-shore bedrock and boulders occurring adjacent to areas of sand which significantly affects the rock. As a consequence of sand-abrasion, wracks such as *Fucus* *vesiculosus* or *Fucus spiralis* are scarce and the community is typically dominated by ephemeral red or green seaweeds, particularly the foliose red seaweed *Porphyra purpurea* and green seaweeds such as *Ulva* spp. Under the blanket of ephemeral seaweeds, the barnacles *Semibalanus balanoides* or *Elminius modestus* and the limpet *Patella vulgata* may occur in the less scoured areas, along with the occasional winkles *Littorina littorea* and *Littorina saxatilis*. Few other species are present (JNCC, 2015).

Depth range

Mid shore

Additional information

-

Listed By

- none -

Further information sources

Search on:

G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

The description of this biotope and information on the characterizing species is taken from Connor *et al.* (2004). The biotope is found where physical disturbance from sand abrasion, prevents the development of a longer-lived biological assemblage, such as the Fucoid dominated biotopes, more typical of stable rocky shores. The LR.FLR.Eph.EntPor biotope is characterized by a dense mat of green seaweeds of the genus *Ulva* or *Ulva* and the foliose red seaweed *Porphyra purpurea*. The genus *Ulva* currently contains 23 taxonomically accepted species (Guiry & Guiry, 2015), although the genus is now more generally accepted as a synonym for *Ulva* (Hayden *et al.*, 2003). Identification of *Ulva* to the species level can be problematic and in some instances species can only be distinguished by experts or by genetic analysis and understanding of the taxonomic relationships between green algal species and higher taxonomic levels is rapidly evolving.

The sensitivity assessments are largely based on *Ulva intestinalis* (formerly *Enteromorpha intestinalis*) and *Ulva lactuca* and *Porphyra purpurea*, as these are typical characterizing species. Due to the high levels of physical disturbance from sand abrasion, the biotope is species poor and animals that do occur in the biotope are found in low abundances. Under the blanket of ephemeral seaweeds, the barnacles *Semibalanus balanoides* or *Elminius modestus* and the limpet *Patella vulgata* may occur in the less scoured areas, along with the occasional winkles *Littorina littorea* and *Littorina saxatilis*. Few other species are present. The sensitivity of these species is not specifically described or used to develop sensitivity assessments as their presence is not considered to be significant in characterizing or structuring the biotope or contributing to ecosystem function. The sensitivity of the associated species are generally not specifically described or used to develop sensitivity assessments as their presence is not considered to be significant in characterizing or structuring the biotope or contributing to ecosystem function. An exception is made for pressures which may result in an increase in abundance in either limpets or littorinids. Experimental manipulation of densities has shown that grazing by these species can remove significant amounts of ephemeral algae and prevent blooms forming (Lein, 1980, Robles 1982, Albrecht, 1998, Jenkins *et al.*, 2005). The biotope is however, maintained by sand abrasion and scour and is considered within the sensitivity assessments where levels may be altered by the pressure.

Resilience and recovery rates of habitat

The *Ulva* spp. and *Porphyra purpurea* that characterize this biotope are classified as opportunistic species that are able to rapidly colonize newly created gaps across a range of sediment types, shore heights, wave exposures and salinity regimes. The life history characteristics that support this opportunism are the broad tolerances for a wide range of conditions (Vermaat & Sand-Jensen, 1987) and high growth and reproduction rates. *Ulva* sp. release zoospores and gametes (collectively called swarmers) to the water column in high numbers. *Ulva* sp. can form the swarmers from normal thallus cells that are transformed into reproductive tissue rather than having to produce specialised reproductive structures (Lersten & Voth, 1960), so that a significant portion of the macroalga's biomass is allocated to the formation of zoospores and gametes (Niesenbaum, 1988). *Ulva* sp. have extended reproduction periods (Smith, 1947) and swarmers are capable of dispersal over a considerable distance. For instance, Amsler & Searles (1980) showed that swarmers of a coastal population of *Ulva* (as *Enteromorpha*) reached exposed artificial substrata on a submarine plateau 35 km away.

The supply of swarmers in vast numbers to the coastline (Niesenbaum, 1988) is reflected in the fast recovery rates of this genus. *Ulva intestinalis* is amongst the first multicellular algae to appear on substrata that have been cleared following a disturbance, e.g. following the *Torrey Canyon* oil spill in March 1967, species of the genus *Ulva r*apidly recruited to areas where oil had killed the herbivores that usually grazed on them, so that a rapid greening of the rocks (owing to a thick coating of *Ulva* spp.) was apparent by mid-May (Smith, 1968). Porphyra is also able to rapidly recruit to cleared substrata, and may regenerate from its discoid shaped holdfast if it remains in situ. After the *Torrey Canyon* oil spill, its presence was noted on rocks within two months of the disturbance.

The red algal *Porphyra purpurea* produces a small, motile conchocelis stage which burrows into wood, rock or the shells of molluscs. This cryptic stage allows *Poprphya purpurea* to survive periods of intense disturbance or grazing which removes adult plants and allows a sudden bloom to form when conditions are suitable (Robles, 1982).

The rapid recruitment of *Ulva* spp. to areas cleared of herbivorous grazers was also demonstrated by Kitching & Thain (1983). Following the removal of the urchin *Paracentrotus lividus* from areas of Lough Hyne, Ireland, *Ulva* grew over the cleared area and reached a coverage of 100% within one year. Such evidence suggests that the biotope characterized by these species would reach maturity relatively rapidly and probably be considered mature in terms of the species present and ability to reproduce within six months.

Other species that are associated with this biotope, including the the barnacle *Semibalanus balanoides* and littorinds generally have slower recovery rates than *Ulva* spp. due to episodic recruitment and slower growth. Where individuals are removed from a small area, adult limpets and *Littorina saxatilis* may recolonize from surrounding patches of habitat where these are present. The barnacles and limpets and the winkle *Littorina littorea* are common, widespread species that spawn annually producing pelagic larvae that can disperse over long distances. It is therefore likely that adjacent populations will provide high numbers of larvae, although recruitment may be low due to habitat unsuitability and the presence of dense *Ulva* spp. preventing settlement . *Littorina saxatilis* however brood young and do not have a pelagic life stage, recovery will therefore depend on the presence of adults in close proximity to impacted areas. As the associated species are present only in some examples of the biotope and occur at low densities when they are present, their absence will not substantially alter the character of the biotope. They are therefore, not specifically considered within the resilience assessments as the biotope can be considered to have recovered before these species re-establish and they are not key species maintaining the biotope. Indeed, as the littorinds graze on the macroalgae characterizing the biotope they can prevent blooms of *Ulva* spp. and *Porphyra* sp. forming (Robles, 1982, Albrecht, 1998) and their presence in large numbers would not benefit this biotope

Resilience assessment. The high recovery potential of the *Ulva* spp. that characterize this biotope, mean that recovery is assessed as ‘High’ (within 2 years) for any level of perturbation (where resistance is ‘None’, ‘Low’, ‘Medium’ or ‘High’. Depending on the season of the impact and level of recovery, the biotope may have recovered within less than six months. It should be noted that this biotope is maintained by chronic disturbance from siltation, substrata instability or changes in salinity that prevent a typical succession process occurring: recovery rates will therefore depend on the recovery of the disturbance regime. Recovery may also be prevented where large numbers of grazers become established, this will again depend on changes in the key environmental factors maintaining the biotope. Where changes would permanently favour grazers recovery would be judged as ‘Very Low’. It should be noted however that some changes in abundance of grazers and algae may be cyclical and part of normal fluctuations within the group of biotopes classified as LR.FLR.Eph.EphX.

NB: 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)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Intertidal species are exposed to extremes of high and low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in this intertidal biotope are therefore generally adapted to tolerate a range of temperatures.

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

Barnacles, *Semibalanus balanoides*, limpets, *Patella vulgata* and littorinids may occur at low densities in this biotope. Laboratory studies suggest that adults of these species can tolerate temperature increases. The median upper lethal temperature limit in laboratory tests on *Littorina littorea*, *Littorina saxatilis* and *Semibalanus balanoides* was approximately 35°C (Davenport & Davenport, 2005). *Patella vulgata* can also tolerate high temperatures. The body temperature of *Patella vulgata* can exceed 36°C in the field, (Davies, 1970); adults become non-responsive at 37-38°C and die at temperatures of 42°C (Evans, 1948).

Although adults may be able to withstand acute and chronic increases in temperature at the pressure benchmark, increased temperatures may have sub-lethal effects on the population by impacting the success of reproduction phases. The distribution of both the key characterizing species, *Semibalanus balanoides* and *Patella vulgata* are 'northern' with their range extending from Portugal or Northern Spain to the Arctic circle. Populations in the southern part of England are therefore relatively close to the southern edge of their geographic range. Reproductive and recruitment success in both species is linked to temperature. Temperatures above 10 to 12 °C inhibit reproduction in *Semibalanus balanoides* (Barnes, 1957 & 1963; Crisp & Patel, 1969; Rognstad *et al*., 2014; Jenkins *et al*., 2000). Increased temperatures are likely to lead to replacement by the warm water species *Chthamalus montagui* and *Chthamalus stellatus* (Southward *et al*., 1995). Increased temperatures may alter spawning cues and reproduction success in *Patella vulgata* populations. Observations suggest that spawning is initiated in autumn storms with greater wave action when seawater temperatures drop below 12 °C (Bowman 1985; Bowman & Lewis; 1986; LeQuesne, 2005). In Northern Portugal warming seas appear to be linked to a shortening of the reproductive period and the lack of multiple spawning events in *Patella vulgata* and other northern species (Ribeiro *et al*., 2009).

Sensitivity assessment. Adults of the key characterizing species, *Porphya purpurea* and *Ulva* spp. and the associated species *Patella vulgata*, *Littorina saxatilis* and *Semibalanus balanoides* and *Patella vulgata* are considered likely to be able to tolerate an acute or chronic increase in temperature at the pressure benchmark, although the timing of acute and chronic increases would alter the degree of impact and hence sensitivity. An acute change occurring on the hottest day of the year and exceeding thermal tolerances would lead to mortality. Sensitivity of *Patella vulgata* and *Semibalanus balanoides* to longer-term, broad-scale perturbations would potentially be greater due to effects on reproduction but these changes may lead to species replacements and are not considered to significantly affect the character of the biotope. *Ulva* spp., are the key characterizing elements that define this biotope and are considered to tolerate increases in temperature at the pressure benchmark. Biotope resistance is therefore assessed as 'High' and recovery as 'High' (by default) so that the biotope is assessed as 'Not sensitive'.

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

Many intertidal species are tolerant of freezing conditions as they are exposed to extremes of low air temperatures during periods of emersion. They must also be able to cope with sharp temperature fluctuations over a short period of time during the tidal cycle. In winter air temperatures are colder than the sea, conversely in summer air temperatures are much warmer than the sea. Species that occur in the intertidal are therefore generally adapted to tolerate a range of temperatures, with the width of the thermal niche positively correlated with the height of the shore that the animal usually occurs at (Davenport & Davenport, 2005).

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

Barnacles, *Semibalanus balanoides*, limpets, *Patella vulgata* and littorinids may occur at low densities in this biotope. Laboratory studies suggest that adults of these species can tolerate temperature decreases. The tolerance of *Semibalanus balanoides* collected in the winter (and thus acclimated to lower temperatures) to low temperatures was tested in the laboratory. The median lower lethal temperature tolerance of *Semibalanus balanoides* collected in winter from Great Cumbrae, Scotland was -14.6 °C (Davenport & Davenport, 2005).The same series of experiments indicated that median lower lethal temperature tolerances for *Littorina saxatilis* and *Littorina littorea* were -16.4 and -13 °C respectively. In experiments *Littorina littorea* were able to tolerate temperatures down to -8 °C for 8 days (Murphy, 1983). In colder conditions an active migration may occur down the shore to a zone where exposure time to the air (and hence time in freezing temperatures) is less.

The limpet, *Patella vulgata* can also tolerate long periods of exposure to the air and can consequently withstand wide variations in temperature. Adults are also largely unaffected by short periods of extreme cold. Ekaratne & Crisp (1984) found adult limpets continuing to grow over winter when temperatures fell to -6°C, and stopped only by still more severe weather. However, loss of adhesion after exposure to -13°C has been observed with limpets falling off rocks and therefore becoming easy prey to crabs or birds (Fretter & Graham, 1994). In the very cold winter of 1962-3 when temperatures repeatedly fell below 0 °C over a period of 2 months large numbers of *Patella vulgata* were found dead (Crisp, 1964). Periods of frost may also kill juvenile *Patella vulgata*, resulting in recruitment failures in some years (Bowman & Lewis, 1977).

The distribution of *Semibalanus balanoides* and *Patella vulgata* are 'northern' with their range extending from Portugal or Northern Spain to the Arctic circle. Over their range they are therefore subject to lower temperatures than in the UK, although distributions should be used cautiously as an indicator of thermal tolerance (Southward *et al*., 1995). The barnacle *Semibalanus balanoides* is primarily a ‘northern’ species with an arctic-boreal distribution. Long-term time series show that recruitment success is correlated to lower sea temperatures (Mieszkowska *et al*., 2014).

Sensitivity assessment. The presence of *Ulva* spp. in arctic regions and the freezing tolerances reported by Vermaat & Sand-Jensen (1987) indicate that *Ulva* spp., would have ‘High’ resistance to decreases in temperature at the acute and chronic benchmarks. Similarly *Porphyra purpurea* are found in regions further north than the UK. The wide temperature tolerance range of *Patella vulgata* and *the* littorinids suggest that the acute and chronic decreases in temperature described by the benchmark would not lead to mortalities. Similarly, based on global temperatures and the link between cooler winter temperatures and reproductive success, *Semibalanus balanoides* is also considered to be unaffected at the pressure benchmark. Based on the characterizing and associated species, this biotope is considered to have ‘High’ resistance and ‘High resilience (by default) to this pressure and is therefore considered to be ‘Not sensitive’. The timing of changes and seasonal weather could result in greater impacts on species. An acute decrease in temperature coinciding with unusually low winter temperatures may exceed thermal tolerances and lead to mortalities of the associated species although this would not alter the character of the biotope.

Salinity increase (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

The biotope typically experiences conditions of full (30-40 psu) or variable (reduced, owing to freshwater runoff) salinity. The key characterizing *Ulva* species can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variations in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime. Alströem-Rapaport *et al*., (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which was considered to partly explain the high rates of colonisation and adaptability of the species.

Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell (1979). Eulittoral zone material showed decreased percentage regeneration in concentrated seawater: 51, 68, 95, 102 & 136 psu) when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). Increased salinity is most likely to occur in the region of the littoral fringe and supralittoral zone and specimens from these areas were able to tolerate very high salinities, a significant decrease in regeneration only being recorded after exposure to concentrated seawater (102 psu and 136 psu) for > 7 days (Reed & Russell, 1979). No applicable evidence was found for salinity tolerance of *Porphyra purpurea*.

In the laboratory, *Semibalanus balanoides* was found to tolerate salinities between 12 and 50 psu (Foster, 1970). Young *Littorina littorea* inhabit rock pools where salinity may increase above 35psu. Thus, key species may be able to tolerate some increase in salinity.

Sensitivity assessment. The characterizing *Ulva* species and the associated species are considered able to tolerate increases in salinity. Based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses it is considered that *Ulva* spp. and the associated littorinids, barnacles and limpets would tolerate a change in salinity from variable or reduced to full and some salinity increases above full salinity. As the associated species occur only in low numbers and do not characterize the biotope the sensitivity assessment is based on the *Ulva* species alone. Biotope resistance is assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

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

The biotope typically experiences conditions of full (30-40 psu) or variable salinity (Connor *et al*., 2004). The key characterizing *Ulva* species can survive hypersaline conditions in supralittoral rockpools subjected to evaporation and is considered to be a very euryhaline species, tolerant of extreme salinities ranging from 0 psu to 136 psu (Reed & Russell, 1979). Some variation in salinity tolerance between populations of *Ulva intestinalis* have been found, however, suggesting that plants have some adaptation to the local salinity regime. Alströem-Rapaport *et al*. (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which was considered to partly explain the high rates of colonisation and adaptability of the species. Reed & Russell (1979) found that the ability to regenerate from cut thalli varied according to the salinity conditions of the original habitat, and that the pattern of euryhalinity in parental material and offspring was in broad agreement (Reed & Russell, 1979). For example; eulittoral zone material showed decreased percentage regeneration in all salinities (dilute: 0, 4.25, 8.5, 17 & 25.5 psu, and concentrated seawater: 51, 68, 95, 102 & 136 psu) except 34 psu, when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*). None of the eulittoral zone material was able to regenerate in freshwater or concentrated seawater, whilst littoral fringe and rock pool material was able to do so.

A change from variable to reduced salinity may however result in the loss of *Porphyra purpurea*. Variants of this biotope occur in areas of freshwater run-off or in reduced salinities but these do not support populations of *Porphyra purpurea* (Connor *et al*., 2004). Reed *et al*. (1980) noted that when transferred from full to slightly reduced salinity water, the photosynthetic rate *of Porphyra purpurea* was temporarily lowered, so reduced salinity may affect the species viability over a longer period of time.

Reduced salinity has also been reported to affect the growth rate of *Ulva intestinalis*. Martins *et al*. (1999) observed that in years with high precipitation and significant increase of freshwater runoff to the Mondego estuary (west Portugal), that *Ulva intestinalis* (as *Enteromorpha intestinalis*) failed to bloom. In the laboratory, the growth rate of *Ulva intestinalis* was measured against a range of salinities, from 0 to 32 psu. *Ulva intestinalis* showed the lowest growth rates at extremely low salinity values (less than or equal to 3 psu), and for salinity less than or equal to 1 psu, the algae died. Growth rates at a salinity lower than 5 psu and higher than 25 psu were also low, in comparison to growth between a salinity of 15 and 20 psu, where *Ulva intestinalis* showed the highest growth rates. Martin *et al*. (1999) concluded that episodes of reduced salinity were an important external parameter in controlling the growth of *Ulva intestinalis*. However, elsewhere *Ulva intestinalis* is known to thrive in areas of the supralittoral zone that receive freshwater runoff. Local conditions may also mediate the ability to tolerate reduced salinities. Kamer & Fong (2001) found that high nitrogen enrichment mitigated the negative effects that reduced salinity had on *Ulva intestinalis* (as *Enteromorpha intestinalis*). Evidence on salinity tolerances was also found for the associated species that occur in low numbers in this biotope. Like other intertidal species these are exposed to changes in salinity resulting from evaporation or run-off and consequently can tolerate changes in salinity. Populations of *Patella vulgata* extend into the mouths of estuaries surviving in salinities down to about 20psu. However, growth and reproduction may be impaired in reduced salinity. Little *et al.* (1991), for example, observed reduced levels of activity in limpets after heavy rainfall and in the laboratory activity completely stopped at 12psu although individuals died only when the salinity was reduced to 3-1psu (Fretter & Graham, 1994). In experiments where freshwater was trickled over the shell Arnold (1957) observed limpets withdrawing and clamping the shell onto the substratum. There appears to be an increasing tolerance of low salinities from the lower to the upper limit of distribution of the species on the shore (Fretter & Graham, 1994) suggesting local acclimation. Similarly, *Semibalanus balanoides* are tolerant of a wide range of salinity and can survive periodic emersion in freshwater, e.g. from rainfall or freshwater run-off, by closing their opercular valves (Foster, 1971b). They can also withstand large changes in salinity over moderately long periods of time by falling into a "salt sleep" and can be found on shores (example from Sweden) with large fluctuations in salinity around a mean of 24 (Jenkins *et al*., 2001). In areas of permanently reduced salinity the Australian barnacle *Austrominius* (formerly *Elminius*) modestus may be favoured, as this species is more tolerant of lower salinities), although this is balanced against its lower tolerance of wave exposure

Littorina littorea is found in waters of full, variable and reduced salinities (Connor *et al*., 2004) and so populations are not likely to be highly intolerant of decreases in salinity. Therefore, it appears that the biotope would have low intolerance to a decrease in salinity. On return to normal conditions recovery is likely to be very rapid.

Sensitivity assessment. The characterizing *Porphyra purpurea* and *Ulva* species and the associated species *Littorina littorea* are considered able to tolerate a change from full to variable salinity. However, a change to reduced salinity may result in the loss of *Porphyra purpurea* and biotope reclassification. Based on reported distributions and the results of experiments to assess salinity tolerance thresholds and behavioural and physiological responses in *Patella vulgata* and *Semibalanus balanoides* it is considered that these species would tolerate a change in salinity from full to variable but that a change from variable to reduced salinity may reduce habitat suitability. As these species occur only in low numbers and do not characterize the biotope the sensitivity assessment is based on the *Ulva* and *Porphyra purpurea* species alone. Biotope resistance, based on a change from full to variable salinity is assessed as 'High' and resilience as 'High', based on no effect to recover from and the biotope is considered to be 'Not sensitive'.

Water flow (tidal current) changes (local)	Medium Q: Low A: NR C: NR	High Q: High A: High C: High	Low Q: Low A: Low C: Low

The key characterizing species of this biotope, *Porphyra purpurea*, *Ulva intestinalis* and *Ulva lactuca* are flexible and conform to the direction of the flow reducing drag and breakage. However, experimental studies show that exposure to currents results in sloughing of tissue and higher current velocities result in breakage of the thallus.

Kennison & Fong (2013) found that *Ulva intestinalis*, settled on ceramic tiles and deployed in the field were subject to greater losses at mean flow speeds of 0.2 m/s (approximately 16 % of biomass) than the 8 % loss from individuals subject to lower flows (0.15 m/s). These results agree with those from another study by Flindt *et al.* (2007) that subjected *Ulva* spp. to increased water flows in flume tanks. They distinguished *Ulva* sp. and *Enteromorpha* sp. in their sloughing experiments but not to species level. Water flow rates were increased from still incrementally by 0.005 m/s and the amount of biomass sloughed off was measured. At a current speed of 0.12 m/s, 3-4% of biomass of *Ulva* sp. was removed, increasing to 4-7% at 0.15 m/s and 40-50% at 0.4 m/s. *Enteromorpha* sp. were slightly more resistant; at current flows of 0.2 m/s 1% of biomass was sloughed, increasing to 20% at 0.35 m/s. Flindt *et al*., (2007) estimated from regression models that the current speeds at which all *Ulva* spp., would be totally removed were 0.82 m/s and 1.28 m/s for *Enteromorpha* sp. Note, *Enteromorpha* is now a synonym of *Ulva*. The authors assume that the *Enteromorpha* sp. mentioned in their study relate to the more filamentous and tube-like growth form of *Ulva intestinalis.*

Modelled predictions of thallus breakage based on laboratory studies of *Ulva lactuca* on bivalve shells estimate that large *Ulva lactuca* (>50 cm in length) are unlikely to persist where currents exceed 0.5 m/s, whereas smaller individuals (24 cm in length) are unlikely to be present where current speeds exceed 1 m/s (Hawes & Smith, 1995). Increased water flows may also be beneficial where these enhance recruitment. Increased water velocities can enhance recruitment through increased larval supply (Kennison & Fong, 2013). Houghton *et al.* (1973) observed that swarmers of *Ulva* were able to settle onto surfaces subjected to water speeds of up to 10.7 knots, suggesting that changes may not inhibit settlement.

Sensitivity assessment. Increased water flow rates may detach and remove biomass of the *Porphyra* sp. and *Ulva* spp. that characterize this biotope. Experiments suggest that the pressure benchmark is biologically relevant, i.e. increases at the pressure benchmark could result in biomass loss and detachment (Flindt *et al*., 2007). The rapid growth of *Porphyra purpurea* and *Ulva* sp. may mitigate the loss of tissue during the growing season. The experiments do not detail the amount of time that individuals were exposed to flows so that extrapolating the results to predicted losses, particularly for breakage is problematic. On exposed shores, wave exposure may also be a more significant factor controlling breakage and sloughing than water flows. Based on the breakage studies (Hawes & Smith, 1995), resistance of *Porphyra purpurea* and *Ulva* sp., to an increase in water flow at the pressure benchmark is assessed as ‘Medium’ as smaller individuals can persist at flow rates that are almost double those of larger plants (Hawes & Smith, 1995). The biotope condition is maintained by sand abrasion; reductions in flow that alter abrasion rates may allow *Rhodothamniella floridula* or fucoids to colonise, altering the character of the biotope. Resistance is assessed as 'Medium' at the pressure benchmark as some transport of sand and deposition would be likely to continue through wave action. Resilience is assessed as 'High' and sensitivity is assessed as 'Low'. Confidence in the resistance assessment is 'Low' as no evidence was found to link changes in water flow with abrasion and sand scour and this is a key factor maintaining the biotope.

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

The biotope occurs on the mid-shore (Connor *et al*., 2004) where chronic disturbance from sand scour prevents the development of a biotope typical of more stable habitat conditions dominated by Fucoids for example, *Fucus spiralis*, *Fucus ceranoides*, or *Pelvetia canaliculata*. Connor *et al*. (2004) report that this biotope is usually found below the zone dominated by *Ulva* spp.. (LR.FLR.Eph.Ent), and above a Fucoid dominated zone where abrasion allows (Connor *et al*., 2004).

Porphyra purpurea is a remarkably desiccation tolerant seaweed being able to lose almost all fluid from its thalli, drying out to a crisp, paper thin film. About 75% of water is lost from the thalli after six hours of exposure (Boney, 1969). While many other seaweeds would die if they lost this much turgidity, Porphyra readily recovers once re-hydrated. Thin seaweeds like Ulva also lose their water content very fast, but overcome the problem by growing in dense populations where they can cover and shade each other to some extent when exposed. As *Ulva intestinalis* is able to tolerate dessication stress it is often very abundant on the high shore where desiccation stress is the primary factor controlling seaweed distribution, and may even be found above the tidal limits of the shore. *Ulva intestinalis* (studied as *Enteromorpha intestinalis*) can survive several weeks of living in completely dried out rock pools, while becoming completely bleached on the uppermost layers, but remaining moist underneath the bleached fronds. However, dessication stress of germlimgs may be lower than adults Hruby & Norton (1979) found that 7-14 day old germlings of *Ulva* (studied as *Enteromorpha*) were more tolerant of desiccation than earlier stages, so an increase in desiccation stress resulting from increased emergence may impact more adversely on newly settled germlings than more mature plants. Over a year an increase in emergence would be considered likely to result in a shift in biotope type to that more typical of the upper shore (LR.FLR.Eph.Ent), with the loss of some *Porphyra purpurea*, rather than the loss of Ulva spp. Owing to increased emergence, the species that graze on *Ulva intestinalis* are likely to be less active, owing to risk of desiccation, and the seaweed may benefit from reduced grazing pressure.

Ulva intestinalis is unlikely to be directly affected by a decrease in the emergence regime, as it occurs in the subtidal zone. However,a decrease in emergence would reduce the effect of the freshwater influences that in some instances maintain the biotope and would increase habitat suitability for some grazers, increasing predation pressure on *Ulva*. spp. However in many instances the biotope develops in areas where sediment instability or sand scour prevents the development of a biotope more typical of rocky shores. As changes in emergence would not alter these structuring factors the biotope may not change substantially.

Increased emergence may reduce habitat suitability for the associated barnacle species, *Semibalanus balanoides. Chthamalus* spp. are more tolerant of desiccation stress than *Semibalanus balnoides* and increased emergence may therefore lead to species replacement although this would not substantially alter the character of the biotope. The mobile species present within the biotope, *Patella vulgata* and the littorinids are able to relocate to preferred shore levels, an increase in emergence may result in migration downshore, while decreased emergence may increase habitat suitability of upper littoral fringe biotopes for these species. Grazing by littornids and other species can have a significant structuring impact on biotopes dominated by ephemeral algae (Robles 1982, Albrecht, 1998). An increase in grazers and grazing within this biotope may removal large amounts of algal biomass preventing blooms.

Sensitivity assessment. This biotope, is considered to be sensitive to increased and decreased emergence. Increased emergence may result in the loss of *Porphyra purpurea* resulting in a shift to the similar biotope LR.FLR.Eph.Ent, which is typically found above this biotope on the shore. Decreased emergence may increase the abundance of littorinids and other grazers and would be likely to reduce the biomass of *Porphyra purpurea* and *Ulva* spp. and may result in an increase in Fucoid cover. Such changes may lead to reclassification to the variant biotope LR.FLR.Eph.BLitX. Resistance to changes in sea level (both an increase and decrease) is assessed as 'Low' and resilience as 'High' (following habitat recovery). Sensitivity is therefore assessed as 'Low'.

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

This biotope occurs in wave exposed or moderately exposed locations (Connor *et al*., 2004). The degree of wave exposure influences significant wave height, as in more exposed areas with a longer fetch, waves would be predicted to be higher. The occurrence of this biotope across two wave exposure categories was considered to indicate, by proxy, that biotopes in the middle of the wave exposure range would tolerate either an increase or decrease in significant wave height at the pressure benchmark.

Changes in wave action (exceeding the pressure benchmark) that result in changes in sediment transport may result in negative effects. The biotope is present where sand scours and abrades the rock, preventing the establishment of fucoids. An increase or decrease in wave action that results in less, or no, sand being deposited on the rocks, due to a lack of re-suspension from source sediments or changes in deposition may lead to a change in the biotope. Reduced abrasion may lead to replacement by the sand-trapping algae *Rhodothamniella floridula* or fucoids which may result in biotope reclassification. Conversely reduced wave action that results in permanent deposition of sediments may lead in the short-term to removal of this biotope due to smothering. Sediment transport processes are influenced by a range of site-specific factors including local sediment supply and topography. A generic assessment is not possible and this indirect effect is not assessed.

Sensitivity assessment. Based on reported distribution (Connor *et al*., 2004), resistance to changes in wave height, at the pressure benchmark, is assessed as 'High', and resilience is also assessed as 'High' by default. The biotope is therefore considered to be '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.

Contamination by non-synthetic chemicals, at levels greater than the pressure benchmark may adversely impact the biotope. The order of metal toxicity to algae varies, with the algal species and experimental conditions, but generally the order is Hg>Cu>Cd>Ag>Pb>Zn (Rice et al., 1973; Rai *et al*., 1981). The effects of copper on macrophytes have been more extensively studied than the effects of any other metal owing to its use in antifouling paints. Lewis *et al*. (1998) investigated the influence of copper exposure and heatshock on the physiology and cellular stress response of *Ulva intestinalis (*as *Enteromorpha intestinalis*). Heat shock proteins (HSPs) are known to be expressed in response to a variety of stress conditions, including heavy metals (Lewis *et al*., 1999). *Ulva intestinalis* was exposed to a range of copper concentrations (0-500 µg -1 for 5 days, to assess the effect of copper exposure on stress proteins (Stress-70 levels) and physiology of the seaweed. Stress-70 was induced by copper exposure, but was found to be no better an indicator of copper exposure than measurement of growth, which is inhibited by copper.

Species of the genus *Ulva* seem to be especially suitable for monitoring heavy metals in coastal areas and estuaries as it is ubiquitous in both and laboratory experiments have shown that accumulation of Cu, Zn, Cd and Pb by four different species of *Ulva* (as *Enteromorpha*) was sufficiently similar to justify pooling samples of the genus for field monitoring (Say *et al*., 1990). However, the interactions of salinity and temperature with toxicity are not always clear and may hinder cross-comparison of samples and surveys. For instance, Munda (1984) found that the Zn, Mn and Co accumulations in *Ulva intestinalis* (as *Enteromorpha intestinalis*) could be enhanced by decreasing the salinity.

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.

Hydrocarbon contamination, at levels greater than the benchmark, e.g. from spills of fresh crude oil or petroleum products, may cause significant loss of *Ulva* spp. Likely effects include smothering, inhibition of respiration and photosynthesis, bleaching and interference with reproduction, so that affected populations may be destroyed. IHowever, the genus tends to recover very rapidly from oil pollution incidents. For instance, after the Torrey Canyon tanker oil in 1967, grazing species were killed, and a dense flush of ephemeral green algae (*Ulva*, *Blidingia*) appeared on the rocky shore within a few weeks and persisted for up to one year (Smith, 1968).

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.

Contamination at levels greater than the benchmark may impact this biotope.Some evidence for adverse effects of chemical pollution on the key characterizing species, *Ulva intestinalis*, has been found. Although herbicides tend not to be used directly in the marine environment, they can enter estuarine areas via river discharge and runoff. Paraquat and 3AT were tested for their effects on the settlement, germination and growth of *Ulva* (as *Enteromorpha*) (Moss & Woodhead, 1975). They found that zygotes were able to develop into filaments in the presence of Paraquat at 7 mg/L, but that germination was deferred at higher concentrations. Zygotes demonstrated increased resistance when they settled in clumps on the substratum, and green thalli of Ulva were more susceptible than ungerminated zygotes. Ulva was more intolerant of 3AT than to Paraquat.

However, synthetic chemicals used as antifouling agents may be directly introduced into the marine environment. Scarlett et al. (1997) analyzed water samples taken from the Plymouth Sound locality for the presence of the s-triazine herbicide, Irgarol 1051, which is an ingredient of antifouling paints used on pleasure boats and ships. Irgarol 1051 was detected at all sampling sites within the Sound; the highest levels were found in close proximity to areas of high boat density, especially where water flow was restricted within marinas, although concentrations within the semi-enclosed Sutton Harbour were less than values predicted from leach rate data. The highest detected concentration of over 120 ng/L significantly inhibited the growth of Ulva intestinalis (as Enteromorpha intestinalis) spores under laboratory conditions; the no effect concentration was 22 ng/L. Photosynthetic efficiency in the adult frond of Ulva intestinalis from Sutton Harbour marina was inhibited by Irgarol 1051 in the laboratory with an EC 50 (72 h) of 2.5 µg/L. A small adverse impact on Ulva intestinalis reproduction within harbours is therefore likely.

Following the *Torrey Canyon* tanker oil spill, copious amounts of solvent based detergents were sprayed directly on to the shore. Algae on the higher shore was especially affected, and included *Ulva intestinalis* (as *Enteromorpha intestinalis*) in high level rock pools where it was killed (Smith, 1968).

Radionuclide contamination	High Q: High A: High C: NR	High Q: High A: High C: High	Not sensitive Q: High A: High C: Low

The key, characterizing *Ulva* spp. are known to be able to acquire large concentrations of substances from surrounding water. In the vicinity of the Sellafield nuclear plant, England, *Ulva* (as *Enteromorpha*) sp. accumulated zirconium, niobium, cerium and plutonium-239, however the species appeared to be unaffected by the radionuclides (Clark, 1997). Based on this evidence, the resistance of the biotope to this pressure at the benchmark, is assessed as 'High', resilience is assessed as 'High' (by default), and the biotope is assessed as 'Not sensitive'.

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

Where nutrients and other factors support rapid growth, large blooms of P*orphyra* spp. and *Ulva* spp. can occur (Wells *et al*., 2014), as these die and decay, they can create anoxic conditions in the water column and the sediments they overlay. Some tolerance for anoxia may therefore be expected that allows a proportion of the population to survive and reproduce during and after these conditions.

Vermaat & Sand-Jensen (1987) tested the survival of discs of *Ulva lactuca* during prolonged exposure to anoxia. The 113 mm^2 discs were taken from wild plants collected in the Roskilde Fjord, Denmark in late autumn. Anoxic conditions were created in the laboratory by bubbling with N_2 gas. Exposure to anoxia for two months did not affect survival but did result in increased respiration and a decrease in growth. Corradi *et al.*, (2006) used similar sized thallus discs from *Ulva* spp. (113 mm^2), collected from the lagoon Sacca di Goro (Po River Delta) during spring to test the effects of hypoxia on gamete production for *Ulva* sp. The test oxygen concentrations ranged from 1.78 – 4.02 μmol /L (the benchmark of 2mg/l refers to 64 μmol/L). The exposure to hypoxia was not lethal to the discs and following resumption of normal oxygen conditions gametes were produced.

Experimental evidence for the associated species *Patella vulgata* and *Semibalanus balanoides* indicate that these species are unlikely to be adversely affected by water column hypoxia at the pressure benchmark. *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). Limpets can survive for a short time in anoxic seawater; Grenon & Walker, (1981) found that in oxygen free water limpets could survive up to 36 hours, although Marshall & McQuaid (1989) found a lower tolerance for *Patella granularis*, which survived up to 11 hours in anoxic water. However, *Patella vulgata* is an intertidal species, being able to respire in air, and in this biotope would only be exposed to low oxygen in the water column intermittently during periods of tidal immersion. In addition, in areas of wave exposure and moderately strong current flow low oxygen levels in the water are unlikely to persist for very long as oxygen levels will be recharged by the incorporation of oxygen in the air into the water column or flushing with oxygenated waters.

In addition, the associated species, *Littorina saxatilis*, like *Patella vulgata*, is an air breather when emersed, so can respire during the tidal cycle.

Sensitivity assessment. No direct evidence for the effects of hypoxia on whole plants in-situ was available. However the results of the laboratory experiments which tested parts of *Ulva* individuals to either prolonged anoxia or short-term hypoxia at levels that exceed the benchmark, indicate that *Ulva* have 'High' resistance to this pressure and 'High' resilience by default. The associated species, littorinids, *Patella vulgata* and *Semibalanus balanoides* are considered to be 'Not Sensitive' to de-oxygenation at the pressure benchmark. The experiments cited as evidence (Grenon & Walker, 1981 and Barnes *et al.*,1963) exceed the duration and/or magnitude of the pressure benchmark. As this biotope occurs in wave exposed conditions or high on the shore some mitigation of hypoxic conditions would be expected from water movements increasing dissolved oxygen in the water column and exposure to air during the tidal emersion cycle. Biotope resistance is therefore assessed as 'High' and resilience as 'High' (no effect to recover from), resulting in a sensitivity of '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

This pressure relates to increased levels of nitrogen, phosphorus and silicon in the marine environment compared to background concentrations. The pressure benchmark is set at compliance with Water Framework Directive (WFD) criteria for good status, based on nitrogen concentration (UKTAG, 2014).

The criteria for status under the WFD with regard to nutrient enrichment is concerned with the presence or absence of 'blooms' of opportunistic algae , including the key characterizing *Porphyra purpurea* and *Ulva* spp. found in this biotope, that act as indicators of enrichment (eutrophication).

The abundance and biomass of these species is used in the implementation of the WFD as indicators to assess condition of waterbodies. The criteria for achieving good status states that there should be: 'limited cover (<15%) and low biomass (<500 g/m^2) of opportunistic macroalgal blooms…macroalgae cover shows slight signs of disturbance with slight deviation from reference conditions' (Wells *et al*., 2014).

The high abundance and biomass of *Porphyra purpurea* and *Ulva* spp, that characterize this biotope would suggest that this biotope would fail to achieve 'good status'. Theoretically, compliance with good status would require a significant loss of characterizing species, suggesting that the biotope would be sensitive to this pressure at the benchmark (i.e. it represents a significant impact for biotope character). However, the biotope is considered to develop in response to chronic physical disturbance from sediment instability or sand-scour, or to freshwater inputs and therefore its presence is not necessarily an indicator of abnormal nutrient loading. Typical blooms of opportunistic macroalgae, occur in sheltered areas such as estuaries (Kennison & Fong, 2013) and are likely to form as unattached mats over sediments rather than rocky shores, the character of these is therefore different to the assessed biotope.

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

Sensitivity assessment. If nutrient levels were to increase (exceeding the pressure benchmark) enhanced growth of *Porphyra purpurea* and *Ulva* spp. would be expected in response and this is not considered to significantly alter the character of the biotope. *Ulva* spp. may decline in response to reductions in nutrient levels, in habitats where other species more typical of undisturbed species are able to recolonize. However, as this biotope is structured by disturbance rather than nutrient enrichment, other species are not considered to establish following decreases in nutrient levels and *Ulva* spp, would be likely to remain the dominant species. The biotope is therefore considered to have 'High' resistance to this pressure and 'High' resilience, (by default) and is assessed as 'Not sensitive'.

Organic enrichment	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No empirical evidence was found to support an assessment for the key characterizing *Porphyra purpurea* and *Ulva* spp., or the associated species; *Semibalanus balanoides*, *Patella vulgata* and *Littorina saxatilis* that are present at low abundances within this biotope. As the characterizing algae species are present in areas of nutrient enrichment (Wells *et al*., 2014) and in turbid conditions they are considered to be unaffected by this pressure, at the benchmark. Organic matter particles in suspension or re-suspended could potentially be utilised as a food resource by the barnacles present within the biotope (Cabral-Oliveira *et al*., 2014) with excess likely to be rapidly removed by wave action. resistance of the biological assemblage within the biotope is considered to be 'High' and resilience was assessed as 'High', so that this biotope is judged to be 'Not sensitive'.

Physical Pressures

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

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

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

This biotope occurs on hard substrata where the key characterizing *Ulva spp*. and *Porphyra purpurea* and the associated species *Semibalanus balanoides* can attach. A soft sedimentary habitat would be unsuitable for these species and the associated species *Patella vulgata* (although littorinids occur on sediment). A change to a soft sedimentary biotope would lead to the development of a biological assemblage more typical of the changed conditions.

Artificial substrata may not support an analogous biotope where the substratum is unsuitable. Tests with stone panels fixed to the sublittoral, mid-tide and high-tide levels of varying roughness found that *Ulva* species settle preferentially on smother, fine grained substratum (chalk, mottled sandstone) and *Porphyra purpurea* on rougher, granulated substratum (limestone, granite, basaltic larvae) (Luther, 1976). Experimental tests with artificial substrates (controlling for grain size) showed that *Ulva* settled in substrates where the grain size was smaller 0.5 mm, while *Porphyra purpurea* settled on substrates >0.5 mm. The population density of *Porphyra purpurea* increased with increasing grain size (Luther, 1976).

Sensitivity assessment. A change to a soft sedimentary habitat would reduce habitat suitability for this biotope, resistance is assessed as 'None' and resilience as 'Very Low' as the change is considered to be permanent. Sensitivity is therefore assessed as 'High'.

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

Not relevant to this biotope which occurs predominantly on bedrock (Connor *et al*., 2004).

Habitat structure changes - removal of substratum (extraction)	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The key characterizing *Ulva* spp., *Porphyra purpurea* and associated species are epifauna or epiflora occurring on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

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

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

The barnacles, limpets and littorinids that occur in low densities in this biotope, have some protection from hard shells or plates but abrasion may damage and kill individuals or detach these. All removed barnacles would be expected to die as there is no mechanism for these to reattach. Removal of limpets and barnacles may result in these being displaced to a less favourable habitat and injuries to foot muscles in limpets may prevent reattachment. Although limpets and littorinids may be able to repair shell damage, broken shells while healing will expose the individual to more risk of desiccation and predation. Evidence for the effects of abrasion are provided by a number of experimental studies on trampling (a source of abrasion) and on abrasion by wave thrown rocks and pebbles.

The effects of trampling on barnacles appears to be variable with some studies not detecting significant differences between trampled and controlled areas (Tyler-Walters & Arnold, 2008). However, this variability may be related to differences in trampling intensities and abundance of populations studied. The worst case incidence was reported by Brosnan & Crumrine (1994) who found that a trampling pressure of 250 steps in a 20x20 cm plot one day a month for a period of a year significantly reduced barnacle cover (*Semibalanus glandula* and *Chthamalus dalli*) at two study sites. Barnacle cover reduced from 66% to 7% cover in 4 months at one site and from 21% to 5% within 6 months at the second site. Overall barnacles were crushed and removed by trampling. Barnacle cover remained low until recruitment the following spring. Long *et al.* (2011) also found that heavy trampling (70 humans /km/hrs) led to reductions in barnacle cover. Single step experiments provide a clearer, quantitative indication of sensitivity to single events of direct abrasion. Povey & Keough (1991) in experiments on shores in Mornington peninsula, Victora, Australia, found that in single step experiments 10 out of 67 barnacles, (*Chthamlus antennatus* about 3mm long), were crushed. However, on the same shore, the authors found that limpets may be relatively more resistant to abrasion from trampling. Following step and kicking experiments, few individuals of the limpet C*ellana trasomerica*, (similar size to *Patella vulgata*) suffered damage or relocated (Povey & Keough, 1991). One kicked limpet (out of 80) was broken and 2 (out of 80) limpets that were stepped on could not be relocated the following day (Povey & Keough, 1991). On the same shore less than 5% of littorinids were crushed in single step experiments (Povey & Keough, 1991).

Shanks & Wright (1986), found that even small pebbles (<6 cm) that were thrown by wave action in Southern California shores could create patches in aggregations of the barnacle, *Chthamalus fissus*, and could smash owl limpets (*Lottia gigantea*). Average, estimated survivorship of limpets at a wave exposed site, with many loose cobbles and pebbles allowing greater levels of abrasion was 40% lower than at a sheltered site. Severe storms were observed to lead to almost total destruction of local populations of limpets through abrasion by large rocks and boulders. In sites with mobile cobbles and boulders increased scour results in lower densities of *Littorina* spp. compared with other, local sites with stable substratum (Carlson *et al*., 2006).

This biotope is found in areas of sand abrasion although the occurrence may be due to the ability to recover quickly from abrasion events that clear the surface, rather than an ability to resist abrasion.

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. In response to a single event of abrasion a proportion of the population of the key characterizing species *Ulva* and *Porphyra purpurea* may be removed, but damaged individuals, *in-situ* would be capable of growth and reproduction. Based on additional evidence for the associated species from the step experiments and the relative robustness of the associated species, the resistance of the biotope, to a single abrasion event is assessed as 'Medium' and recovery as 'High', so that sensitivity is assessed as 'Low'. Resistance will be lower (and hence sensitivity greater) to abrasion events that exert a greater crushing force than the trampling examples the assessment is based on). It should be noted that abrasion and other disturbance factors such as sediment instability are important to the maintenance of this biotope. The opportunistic species can rapidly colonise where cleared surfaces and removal of predators allows the development of a bloom (Robles 1982).

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

The species characterizing this biotope group are epifauna or epiflora occurring on rock which is resistant to subsurface penetration. The assessment for the abrasion pressure is therefore considered to equally represent sensitivity to this pressure.

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

Intertidal biotopes will only be exposed to this pressure when submerged during the tidal cycle and thus have limited exposure. Siltation, which may be associated with increased suspended solids and the subsequent deposition of these is assessed separately (see siltation pressures).

As a photoautotroph, the key characterizing *Ulva* spp., are likely to benefit from reduced turbidity, as the light attenuating effects of turbid water reduce photosynthesis and *Ulva* sp. and *Porphyra* sp. were present on upper shores in an area where total suspended solids were very low ('Clear' on the UK TAG (2014) scale), Shepherd *et al*., (2009).

Experiments have shown that *Ulva* is a shade tolerant species and can compensate for reduced irradiance by increasing chlorophyll concentration and light absorption at low light levels. *Ulva* spp. were able to survive over two months in darkness and to begin photosynthesising immediately when returned to the light (Vermaat & Sand-Jensen, 1987). Limited shading from suspended sediments is therefore not considered to negatively affect this genus. Suspended sediments may however have abrading effects on the fronds pf *Porphyra purpurea* and *Ulva* spp. Tolhurst *et al*. (2007) found that *Ulva intestinalis* germlings kept in tanks and exposed to 100 mg/l of suspended sediment showed reduced growth. Similarly, Hyslop & Davies (1998) found that *Ulva lactuca* lost weight when kept in flasks with 1 g/l of colliery waste that was shaken for 1 hour every day for 8 days. The experimental solids level, however, exceeds the pressure benchmark.

Sensitivity assessment. The exposure of this upper shore biotope to suspended sediments in the water column will be limited to the short immersion periods, however silts deposited on the leaves during emersion may remain on the fronds inhibiting photosynthesis in sheltered areas. The biotope is considered to be 'Not sensitive' to a reduction in suspended solids, although this may reduce food supply to the barnacles that occur in this biotope. An increase in suspended solids may lead to some sub-lethal abrasion of fronds but this will be compensated by the high growth rates exhibited by *Porphyra purpurea* and *Ulva* spp. Resistance is therefore assessed as 'High' and resilience as 'High' (by default) so that the biotope is considered to be 'Not sensitive'.

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

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen , (1987) exposed thallus discs (113 mm^2) of *Ulva lactuca* to darkness and anoxia and sulphides at winter temperatures. It was found that these conditions did not affect survival over two months, although exposure to anoxia increased respiration and reduced growth (Vermaat & Sand-Jensen, 1987). These experiments were undertaken using *Ulva lactuca* collected from Roskilde Fjord, Denmark. Corradi *et al*., (2006) subjected *Ulva* sp. collected from the Sacca di Goro, Italy to similar stressors (hypoxia 1.78 – 4.02 µmol /L, or sulphide at 1mM, both treatments in darkness) for 3,5 or 7days at 20°C. The thallus discs survived but no gametes were produced until recovery in oxygenated conditions. The high tolerance of darkness, anoxia and hydrogen sulphides allows buried fragments of *Ulva* sp. to overwinter, protected from frosts. Kamermans *et al*., (1998) found that parts of *Ulva* thalli that were collected from the Veerse Meer lagoon in the Netherlands could resume growth in the spring when returned to the surface. *Ulva* spp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* spp. in this biotope.

Although *Ulva* spp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggest that resistance to this pressure may be lower. *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977) although Littler *et al*., (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonise sand-scoured areas (such as this biotope). *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003, references therein) suggesting that resistance to chronic rather than acute siltation events may be higher. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Airoldi, 2003). Hyslop *et al*. (1997) compared the composition, abundance and distribution of dominant plants and animals at several rocky shores affected or unaffected by dumping of colliery wastes along the coastline of northeast England. They reported that while the distribution of animals was not related to colliery wastes, diversity of macroalgae was significantly negatively correlated with colliery waste inputs and particularly dramatic reductions in cover at the affected sites were observed for *Ulva lactuca*. The authors suggested that, because colliery waste leaches much of its toxic chemical content into the sea, detrimental effects were most likely related to the physical presence of sediments.

The associated species, *Patella vulgata*, *Semibalanus balanoides* and *Littorina saxatilis* are likely to be negatively affected by siltation although no direct evidence was found for the sensitivity of the latter two. The lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear. Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit grazing and result in loss of attachment and death after a few days Airoldi & Hawkins (2007). The laboratory experiments are supported by observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England as *Patella vulgata* abundances were higher where deposits were absent (Airoldi & Hawkins (2007). Littler *et al*., (1983) found that the another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. Even small deposits of sediments are likely to result in local removal of limpets and limpets are considered to have 'Low' resistance to this pressure based primarily on observations and experiments of Airoldi & Hawkins, (2007). The sensitivity assessment for the biotope is based on *Ulva* spp. Siltation by 5 cm of fine sediments is considered to remove a proportion of the population through scour effects and resistance is assessed as 'Low-Medium', recovery is assessed as 'High' and sensitivity is assessed as 'Low'. Siltation may be a factor in allowing this biotope to develop where it removes grazers and creates space for colonisation by *Porphyra* sp. and *Ulva* sp. (Robles, 1982).

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

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Although *Ulva* spp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggest that resistance to this pressure may be lower. *Ulva lactuca* is a dominant species on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), although Littler *et al*., (1983) suggest that *Ulva* sp., are present in areas periodically subject to sand deposition not because they are able to withstand burial but because they are able to rapidly colonise sand-scoured areas (such as this biotope). *Ulva* spp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003, references therein) suggesting that resistance to low-level chronic rather than acute siltation events may be higher. In general, propagules, early post-settlement stages and juveniles suffer severe stress and mortality from sediments (Airoldi, 2003). Hyslop *et al*. (1997) compared the composition, abundance and distribution of dominant plants and animals at several rocky shores affected or unaffected by dumping of colliery wastes along the coastline of northeast England. They reported that while the distribution of animals was not related to colliery wastes, diversity of macroalgae was significantly negatively correlated with colliery waste inputs and particularly dramatic reductions in cover at the affected sites were observed for *Ulva lactuca*. The authors suggested that, because colliery waste leaches much of its toxic chemical content into the sea, detrimental effects were most likely related to the physical presence of sediments.

The associated species, *Patella vulgata*, *Semibalanus balanoides* and *Littorina saxatilis* are likely to be negatively affected by siltation although no direct evidence was found for the sensitivity of the latter two. The lower limits of *Semibalanus balanoides* (as *Balanus balanoides*) appear to be set by levels of sand inundation on sand-affected rocky shores in New Hampshire (Daly & Mathieson, 1977), suggesting that this species is sensitive to the deposition of relatively coarse sediments, although whether this is due to repeated scour events removing juveniles rather than siltation effects (i.e. smothering, prevention of feeding) is not clear. Experiments have shown that the addition of even thin layers of sediment (approximately 4 mm) inhibit grazing and result in loss of attachment and death after a few days (Airoldi & Hawkins, 2007) . The laboratory experiments are supported by observations on exposed and sheltered shores with patches of sediment around Plymouth in the south west of England as *Patella vulgata* abundances were higher where deposits were absent (Airoldi & Hawkins, 2007). Littler *et al*., (1983) found that the another limpet species, *Lottia gigantea* on southern Californian shores was restricted to refuges from sand burial on shores subject to periodic inundation by sands.

Sensitivity assessment. The available evidence indicates that *Ulva* spp. can survive some of the stressors associated with burial but would be sensitive to abrasion and scouring forces resulting from the deposition and removal of sediments. Even small deposits of sediments are likely to result in local removal of limpets and limpets are considered to have 'Low' resistance to this pressure based primarily on observations and experiments of Airoldi & Hawkins, (2007). The sensitivity assessment for the biotope is based on *Ulva* spp. as no evidence was found for *Porphyra purpurea*. Siltation by 30 cm of fine sediments is considered to remove a large proportion of the population through scour effects and resistance is assessed as 'Low', recovery is assessed as 'High' and sensitivity is assessed as 'Low'. Siltation may be a factor in allowing this biotope to develop where it removes grazers and creates space for colonisation by *Porphyra purpurea* and *Ulva* sp (Robles, 1982).

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	No evidence (NEv) 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

Not relevant.

Introduction of light or shading	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

A number of experiments have demonstrated that the key characterizing species *Ulva lactuca*, has high tolerance for shading and can survive periods of darkness. Vermaat & Sand-Jensen (1987) found that *Ulva lactuca*, collected from Roskilde Fjord in Denmark in late autumn had extremely high shade tolerances. Increasing chlorophyll concentration and light absorption allowed the individuals (studied experimentally as thallus discs of 113mm^2) to continue to grow at the lowest irradiance tested (0.6 µE m^2/s). This corresponds to the lowest light-levels of deep-living marine macroalgae and phytoplankton growing under ice (Vermaat & Sand-Jensen, 1987). *Ulva lactuca* was able to survive two months in darkness and was able to resume growth immediately when transferred to the light (Vermaat & Sand-Jensen, 1987). *Porphyra purpurea* can also acclimate to low light levels and continue growth (Markager, 1993).

No direct evidence to assess this pressure was found for the key characterizing species *Patella vulgata* and the littorinids. As both species occur on open rock and in crevices and *under Fucus canopies* they are considered tolerant of a range of light conditions. Light levels have, however been demonstrated to influence a number of phases of the reproductive cycle in *Semibalanus balanoides*. In general light inhibits aspects of the breeding cycle. Penis development is inhibited by light (Barnes & Stone, 1972) while Tighe-Ford (1967) showed that constant light inhibited gonad maturation and fertilization. Davenport & Crisp (unpublished data from Menai Bridge, Wales, cited from Davenport *et al*., 2005) found that experimental exposure to either constant darkness, or 6 h light: 18 h dark photoperiods induced autumn breeding in *Semibalanus*. They also confirmed that very low continuous light intensities (little more than starlight) inhibited breeding. Latitudinal variations in timing of the onset of reproductive phases (egg mass hardening) have been linked to the length of darkness (night) experienced by individuals rather than temperature (Davenport *et al*., 2005). Changes in light levels associated with climate change (increased cloud cover) were considered to have the potential to alter timing of reproduction (Davenport *et al*., 2005) and to shift the range limits of this species southward. 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 for this species.

Sensitivity assessment. Changes in light levels from anthropogenic sources may have the potential to alter reproduction in *Semibalanus balanoides*, however it is not clear how these effects would ramify to the population level. The key *Ulva* spp. that characterizes the biotope are considered to have 'High' resistance to changes in light level, although extreme changes such as complete darkness would prevent photosynthesis and growth and high light levels may be damaging. Recovery is assessed as 'High' by default and the biotope is judged to be 'Not sensitive '.

Barrier to species movement	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

No direct evidence was found to assess this pressure. The key characterizing Ulva spp. produce large amounts of motile swarmers, throughout the growing season (Niesenbaum, 1988) . The level of supply of potential recruits is considered to be so great that barriers and changes in tidal excursion will not negatively impact populations. The associated species *Patella vulgata* and *Semibalanus balanoides* also produce planktonic larvae that are transported by water movements.. Barriers that reduce the degree of tidal excursion may alter larval supply to suitable habitats from source populations. Conversely the presence of barriers may enhance local population supply by preventing the loss of larvae from enclosed habitats. *Littorina saxatilis* have either limited dispersal or produce crawl away juveniles rather than pelagic larvae (direct development). Barriers and changes in tidal excursion are not considered relevant to these species as dispersal is limited. As the key characterizing *Ulva* spp. species are widely distributed and have larvae capable of long distance transport, resistance to this pressure is assessed as 'High' and resilience as 'High' by default. This biotope is therefore considered to be 'Not sensitive'.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant' to seabed habitats. NB. Collision by grounding vessels is addressed under 'surface abrasion'.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Not relevant.

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

The key characterizing *Ulva* spp. may be cultivated for use as biofilters to mitigate pollution, as biomass for biofuel generation or for pharmaceuticals and food. No information was found on current production in the UK and no evidence was found for the effects of gene flow between cultivated species and wild populations. As wild populations are widely distributed and water flow may aid dispersal of swarmers, populations are not considered to be genetically isolated. It is, therefore, considered that resistance to changes in genetic structure is 'High' and that resilience is, therefore 'High' by default and the biotope is 'Not sensitive'. The use of genetically modified organisms in the future, which may transfer novel genetic material to wild populations may result in harmful impacts and this assessment would require updating if such scenarios arise.

Introduction or spread of invasive non-indigenous species	High Q: Low A: NR C: NR	High Q: High A: High C: High	Not sensitive Q: Low A: Low C: Low

This biotope occurs where either fresh-water influences or physical disturbances, such as abrasion, prevent the development of a more diverse rocky shore assemblage. Due to the environmental stressors that maintain the biotope, the habitat is unsuitable for colonization by most species including invasive, non-indigenous species. The non-indigenous barnacle *Austrominius modestus* (formerly *Elminius modestus*), may replace the native *Semibalanus balanoides*, particularly in sheltered areas or where salinity is reduced. This is not considered to significantly alter the character of the biotope.

Sensitivity assessment. Based on the high levels of environmental stress and the lack of habitat overlap and reported impacts with currently recognised invasive, non-indigenous species, this biotope is considered to have 'High' resistance and 'High' resilience to this pressure and is therefore assessed as 'Not sensitive'.

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

No evidence was found to suggest that pathogens cause mass mortalities in the key characterizing species. The biotope is therefore assessed as 'Not sensitive' and resistance and resilience are assessed as 'High'.

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

The winkle *Littorina littorea* and the limpet *Patella vulgata* occur in low densities in this biotope and may be gathered by hand. However, as these are not key characterizing species the biotope is not considered sensitive to their removal. Removal of these species may also be beneficial to the characterizing algae species by reducing grazing. *Porphyra*, commonly known as 'laver', may be hand gathered in some locations. The key characterizing *Ulva* spp. may also be collected from the wild for use in pharmaceuticals and food. Removal of both species in high quantities would alter the character of the biotope, resulting in reclassification. Resistance to harvesting is assessed as 'Low' as the genus, is relatively large, attached and accessible and therefore has no escape or other avoidance mechanisms. Resilience is assessed as 'High' as cleared areas will be readily colonized. Sensitivity is, therefore, assessed as 'Low'.

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

Incidental removal of the characterizing *Ulva and Porphyra* species would alter the character of the biotope. The ecological services such as primary production provided by these species would also be lost.

Sensitivity assessment. Removal of a large percentage of the characterising species would alter the character of the biotope so that it was bare rock. Resistance is therefore assessed as 'Low' and recovery as 'High' and sensitivity is therefore assessed as 'Low'.

Bibliography

Abou-Aisha, K.M., Kobbia, I., El Abyad, M., Shabana, E.F. & Schanz, F., 1995. Impact of phosphorus loadings on macro-algal communities in the Red Sea coast of Egypt. *Water, Air, and Soil Pollution*, **83** (3-4), 285-297.

Airoldi, L., 2003. The effects of sedimentation on rocky coast assemblages. *Oceanography and Marine Biology: An Annual Review*, **41**,161-236

Airoldi, L. & Hawkins, S.J., 2007. Negative effects of sediment deposition on grazing activity and survival of the limpet *Patella vulgata*. *Marine Ecology Progress Series*, **332**, 235-240.

Albrecht, A.S., 1998. Soft bottom versus hard rock: Community ecology of macroalgae on intertidal mussel beds in the Wadden Sea. *Journal of Experimental Marine Biology and Ecology*, **229** (1), 85-109.

Alströem-Rapaport, C., Leskinen, E. & Pamilo, P., 2010. Seasonal variation in the mode of reproduction of *Ulva intestinalis* in a brackish water environment. *Aquatic Botany*, **93** (4), 244-249.

Amsler, C.D. & Searles, R.B., 1980. Vertical distribution of seaweed spores in a water column off shore of North Carolina. *Journal of Phycology*, **16**, 617-619.

Arnold, D.C., 1957. The response of the limpet, *Patella vulgata* L., to waters of different salinities. *Journal of the Marine Biological Association of the United Kingdom*, **36**, 121-128.

Baeck, S., Lehvo, A. & Blomster, J., 2000. Mass occurrence of unattached *Enteromorpha intestinalis* on the Finnish Baltic Sea coast. *Annales Botanici Fennici*, **37**, 155-161.

Barnes, H. & Stone, R., 1972. Suppression of penis development in *Balanus balanoides* (L.). *Journal of Experimental Marine Biology and Ecology*, **9** (3), 303-309.

Barnes, H., 1957. Processes of restoration and synchronization in marine ecology. The spring diatom increase and the 'spawning' of the common barnacle *Balanus balanoides* (L.). *Année Biologique. Paris*, **33**, 68-85.

Barnes, H., 1963. Light, temperature and the breeding of *Balanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, **43** (03), 717-727.

Barnes, H., Finlayson, D.M. & Piatigorsky, J., 1963. The effect of desiccation and anaerobic conditions on the behaviour, survival and general metabolism of three common cirripedes. *Journal of Animal Ecology*, **32**, 233-252.

Boney, A.D., 1969. *A biology of marine algae*. London: Hutchinson International.

Bowman, R.S., 1985. The biology of the limpet *Patella vulgata* L. in the British Isles: spawning time as a factor determining recruitment sucess. In *The Ecology of Rocky Coasts: essays presented to J.R. Lewis, D.Sc.*, (ed. P.G. Moore & R. Seed), Hodder and Stoughton, London, pages 178-193.

Bowman, R.S. and Lewis, J.R., 1986. Geographical variation in the breeding cycles and recruitment of *Patella* spp. *Hydrobiologia*, **142**, 41-56.

Bowman, R.S. & Lewis, J.R., 1977. Annual fluctuations in the recruitment of *Patella vulgata* L. *Journal of the Marine Biological Association of the United Kingdom*, **57**, 793-815.

Brosnan, D.M. & Crumrine, L.L., 1994. Effects of human trampling on marine rocky shore communities. *Journal of Experimental Marine Biology and Ecology*, **177**, 79-97.

Cabral-Oliveira, J., Mendes, S., Maranhão, P. & Pardal, M., 2014. Effects of sewage pollution on the structure of rocky shore macroinvertebrate assemblages. *Hydrobiologia*, **726** (1), 271-283.

Carlson, R.L., Shulman, M.J. & Ellis, J.C., 2006. Factors Contributing to Spatial Heterogeneity in the Abundance of the Common Periwinkle *Littorina Littorea* (L.). *Journal of Molluscan Studies*, **72** (2), 149-156.

Clark, R.B., 1992. *Marine pollution*, 3rd edition. Oxford: Clarendon Press.

Clark, R.B., 1997. *Marine Pollution*, 4th ed. Oxford: Carendon Press.

Cole, K. & Conway, E., 1980. Studies in the Bangiaceae: reproductive modes. *Botanica Marina*, **23**, 545-553.

Connor, D.W., Allen, J.H., Golding, N., Howell, K.L., Lieberknecht, L.M., Northen, K.O. & Reker, J.B., 2004. The Marine Habitat Classification for Britain and Ireland. Version 04.05. ISBN 1 861 07561 8. In JNCC (2015), *The Marine Habitat Classification for Britain and Ireland Version 15.03.* [2019-07-24]. Joint Nature Conservation Committee, Peterborough. Available from https://mhc.jncc.gov.uk/

Connor, D.W., Brazier, D.P., Hill, T.O., & Northen, K.O., 1997b. Marine biotope classification for Britain and Ireland. Vol. 1. Littoral biotopes. *Joint Nature Conservation Committee, Peterborough, JNCC Report* no. 229, Version 97.06., *Joint Nature Conservation Committee, Peterborough, JNCC* Report No. 230, Version 97.06.

Corradi, M.G., Gorbi, G. & Zanni, C., 2006. Hypoxia and sulphide influence gamete production in *Ulva* sp. *Aquatic Botany*, **84** (2), 144-150.

Crisp, D. & Patel, B., 1969. Environmental control of the breeding of three boreo-arctic cirripedes. *Marine Biology*, **2** (3), 283-295.

Daly, M.A. & Mathieson, A.C., 1977. The effects of sand movement on intertidal seaweeds and selected invertebrates at Bound Rock, New Hampshire, USA. *Marine Biology*, **43**, 45-55.

Davenport, J. & Davenport, J.L., 2005. Effects of shore height, wave exposure and geographical distance on thermal niche width of intertidal fauna. *Marine Ecology Progress Series*, **292**, 41-50.

Davenport, J., Berggren, M.S., Brattegard, T., Brattenborg, N., Burrows, M., Jenkins, S., McGrath, D., MacNamara, R., Sneli, J.-A. & Walker, G., 2005. Doses of darkness control latitudinal differences in breeding date in the barnacle *Semibalanus balanoides*. *Journal of the Marine Biological Association of the United Kingdom*, **85** (01), 59-63.

Davies, C.E. & Moss, D., 1998. European Union Nature Information System (EUNIS) Habitat Classification. *Report to European Topic Centre on Nature Conservation from the Institute of Terrestrial Ecology, Monks Wood, Cambridgeshire.* [Final draft with further revisions to marine habitats.], Brussels: European Environment Agency.

Davies, S.P., 1970. Physiological ecology of *Patella* IV. Environmental and limpet body temperatures. *Journal of the Marine Biological Association of the United Kingdom*, **50** (04), 1069-1077.

Ekaratne, S.U.K. & Crisp, D.J., 1984. Seasonal growth studies of intertidal gastropods from shell micro-growth band measurements, including a comparison with alternative methods. *Journal of the Marine Biological Association of the United Kingdom*, **64**, 183-210.

Evans, R.G., 1948. The lethal temperatures of some common British littoral molluscs. *The Journal of Animal Ecology*, **17**, 165-173.

Flindt, M.R., Pedersen, C.B., Amos, C.L., Levy, A., Bergamasco, A. & Friend, P., 2007. Transport, sloughing and settling rates of estuarine macrophytes: Mechanisms and ecological implications. *Continental Shelf Research*, **27** (8), 1096-1103.

Foster, B.A., 1970. Responses and acclimation to salinity in the adults of some balanomorph barnacles. *Philosophical Transactions of the Royal Society of London, Series B*, **256**, 377-400.

Foster, B.A., 1971b. On the determinants of the upper limit of intertidal distribution of barnacles. *Journal of Animal Ecology*, **40**, 33-48.

Fretter, V. & Graham, A., 1994. *British prosobranch molluscs: their functional anatomy and ecology*, revised and updated edition. London: The Ray Society.

Grenon, J.F. & Walker, G., 1981. The tenacity of the limpet, *Patella vulgata* L.: an experimental approach. *Journal of Experimental Marine Biology and Ecology*, **54**, 277-308.

Hawes, I. & Smith, R., 1995. Effect of current velocity on the detachment of thalli of *Ulva lactuca* (Chlorophyta) in a New Zealand estuary. *Journal of Phycology*, **31** (6), 875-880.

Hawkins, S. J. & Jones, H. D., 1992. *Rocky Shores*. London: Immel.

Hayden, H.S., Blomster, J., Maggs, C.A., Silva, P.C., Stanhope, M.J. & Waaland, J.R., 2003. Linnaeus was right all along: *Ulva* and *Enteromorpha* are not distinct genera. *European Journal of Phycology*, **38**, 277-294.

Hetherington, J.A., 1976. *Radioactivity in surface and coastal waters of the British Isles.* Fisheries Radiobiological Laboratory Technical Report, 11, 1-35.

Hill, S., Burrows, S.J. & Hawkins, S.J., 1998. *Intertidal Reef Biotopes (Volume VI). An overview of dynamics and sensitivity characteristics for conservation management of marine Special Areas of Conservation.* Oban: Scottish Association for Marine Science (UK Marine SACs Project)., Scottish Association for Marine Science (UK Marine SACs Project).

Houghton, D.R., Pearman, I. & Tierney, D., 1973. The effect of water velocity on the settlement of swarmers of the green alga *Enteromorpha*. In *Proceedings of the third international congress on marine corrosion and fouling* (ed. R.F. Acker, B. Floyd Brown, J.R. DePalma & W.P. Iverson), 682-690. Evanston, Northwestern University Press.

Hruby, T. & Norton, T.A., 1979. Algal colonization on rocky shores in the Firth of Clyde. *Journal of Ecology*, **67**, 65-77.

Hyslop B.T. & Davies, M.S., 1998. Evidence for abrasion and enhanced growth of *Ulva lactuca* L. in the presence of colliery waste particles. *Environmental Pollution*, **101** (1), 117-121.

Hyslop, B.T., Davies, M.S., Arthur, W., Gazey, N.J. & Holroyd, S., 1997. Effects of colliery waste on littoral communities in north-east England. *Environmental Pollution*, **96** (3), 383-400.

Jenkins, S., Åberg, P., Cervin, G., Coleman, R., Delany, J., Della Santina, P., Hawkins, S., LaCroix, E., Myers, A. & Lindegarth, M., 2000. Spatial and temporal variation in settlement and recruitment of the intertidal barnacle *Semibalanus balanoides* (L.)(Crustacea: Cirripedia) over a European scale. *Journal of Experimental Marine Biology and Ecology*, **243** (2), 209-225.

Jenkins, S.R., Beukers-Stewart, B.D. & Brand, A.R., 2001. Impact of scallop dredging on benthic megafauna: a comparison of damage levels in captured and non-captured organisms. *Marine Ecology Progress Series*, **215**, 297-301.

JNCC, 2015. The Marine Habitat Classification for Britain and Ireland Version 15.03. (20/05/2015). Available from https://mhc.jncc.gov.uk/

JNCC (Joint Nature Conservation Committee), 1999. *Marine Environment Resource Mapping And Information Database (MERMAID): Marine Nature Conservation Review Survey Database.* [on-line] http://www.jncc.gov.uk/mermaid

Kain, J.M., & Norton, T.A., 1990. Marine Ecology. In *Biology of the Red Algae*, (ed. K.M. Cole & Sheath, R.G.). Cambridge: Cambridge University Press.

Kamer, K. & Fong, P., 2001. Nitrogen enrichment ameliorates the negative effects of reduced salinity on green macroalga *Enteromorpha intestinalis*. *Marine Ecology Progress Series*, **218**, 87-93.

Kamermans, P., Malta, E.-j., Verschuure, J.M., Lentz, L.F. & Schrijvers, L., 1998. Role of cold resistance and burial for winter survival and spring initiation of an *Ulva* spp.(Chlorophyta) bloom in a eutrophic lagoon (Veerse Meer lagoon, The Netherlands). *Marine Biology*, **131** (1), 45-51.

Kennison, R.L. & Fong, P., 2013. High amplitude tides that result in floating mats decouple algal distribution from patterns of recruitment and nutrient sources. *Marine Ecology Progress Series*, **494**, 73-86.

Kinne, O. (ed.), 1972. *Marine Ecology: A Comprehensive, Integrated Treatise on Life in Oceans and Coastal Waters*,Vol.1, *Environmental Factors*, part 3. New York: John Wiley & Sons.

Kitching, J.A. & Thain, V.M., 1983. The ecological impact of the sea urchin *Paracentrotus lividus* (Lamarck) in Lough Ine, Ireland. *Philosophical Transactions of the Royal Society of London, Series B*, **300**, 513-552.

Kraufvelin, P., 2007. Responses to nutrient enrichment, wave action and disturbance in rocky shore communities. *Aquatic Botany*, **87** (4), 262-274.

Kylin, H., 1917. Kalteresistenze der Meerealen. *Bericht der Deutschen Botanischen Gesellschafter*, **35**, 370-384.

Leal, M.L.F., Vascencelos, M.T., Sousa-Pinto, I. & Cabral, J.P.S., 1997. Biomonitoring with benthic macroalgae and direct assay of heavy metals in seawater of the Oporto coast (northwest Portugal) *Marine Pollution Bulletin*, **34**, 1006-1015.

Le Quesne W.J.F. 2005. *The response of a protandrous species to exploitation, and the implications for management: a case study with patellid limpets*. PhD thesis. University of Southampton, Southampton, United Kingdom.

Lersten, N.R. & Voth, P.D., 1960. Experimental control of zoid discharge and rhizoid formation in the green alga Enteromorpha. *Botanical Gazette*, **122**, 33-45.

Lewis, S., May, S., Donkin, M.E. & Depledge, M.H., 1998. The influence of copper and heat shock on the physiology and cellular stress response of *Enteromorpha intestinalis*. *Marine Environmental Research*, **46**, 421-424.

Littler, M.M., Martz, D.R. & Littler, D.S., 1983. Effects of recurrent sand deposition on rocky intertidal organisms: importance of substrate heterogeneity in a fluctuating environment. *Marine Ecology Progress Series*. **11** (2), 129-139.

Lobban, C.S. & Harrison, P.J., 1997. *Seaweed ecology and physiology*. Cambridge: Cambridge University Press.

Long, J.D., Cochrane, E. & Dolecal, R., 2011. Previous disturbance enhances the negative effects of trampling on barnacles. *Marine Ecology Progress Series*, **437**, 165-173.

Luther, G., 1976. Bewuchsuntersuchungen auf Natursteinsubstraten im Gezeitenbereich des Nordsylter Wattenmeeres: Algen. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, 28 (3-4), 318-351.

Markager, S., 1993. Light absorption and quantum yield for growth in five species of marine macroalgae. *Journal of Phycology*, **29** (1), 54-63.

Marshall, D.J. & McQuaid, C.D., 1989. The influence of respiratory responses on the tolerance to sand inundation of the limpets *Patella granularis* L.(Prosobranchia) and *Siphonaria capensis* Q. et G.(Pulmonata). *Journal of Experimental Marine Biology and Ecology*, **128** (3), 191-201.

Martinez, B., Pato, L.S. & Rico, J.M., 2012. Nutrient uptake and growth responses of three intertidal macroalgae with perennial, opportunistic and summer-annual strategies. *Aquatic Botany*, **96** (1), 14-22.

Martins, I., Oliveira, J.M., Flindt, M.R. & Marques, J.C., 1999. The effect of salinity on the growth rate of the macroalgae *Enteromorpha intestinalis* (Chlorophyta) in the Mondego estuary (west Portugal). *Acta Oecologica*, **20** (4), 259-265.

McAllen, R., 1999. *Enteromorpha intestinalis* - a refuge for the supralittoral rockpool harpacticoid copepod *Tigriopus brevicornis*. *Journal of the Marine Biological Association of the United Kingdom*, **79**, 1125-1126.

Mieszkowska, N., Burrows, M.T., Pannacciulli, F.G. & Hawkins, S.J., 2014. Multidecadal signals within co-occurring intertidal barnacles *Semibalanus balanoides* and *Chthamalus* spp. linked to the Atlantic Multidecadal Oscillation. *Journal of Marine Systems*, **133**, 70-76.

Moss, B.L. & Woodhead, P., 1975. The effect of two commercial herbicides on the settlement, germination and growth of *Enteromorpha*. *Marine Pollution Bulletin*, **6**, 189-192.

Munda, I.M., 1984. Salinity dependent accumulation of Zn, Co and Mn in *Scytosiphon lomentaria* (Lyngb.) Link and *Enteromorpha intestinalis* (L.) from the Adriatic Sea. *Botanica Marina*, **27**, 371-376.

Newell, R.C., 1979. *Biology of intertidal animals*. Faversham: Marine Ecological Surveys Ltd.

Niesenbaum R.A., 1988. The ecology of sporulation by the macroalga *Ulva lactuca* L. (chlorophyceae). *Aquatic Botany*, **32**, 155-166.

Pedersen, M.F., Borum, J. & Fotel, L. F., 2009. Phosphorus dynamics and limitation of fast and slow-growing temperate seaweeds in Oslofjord, Norway. *Marine Ecology Progress Series*, **399**, 103-115

Povey, A. & Keough, M.J., 1991. Effects of trampling on plant and animal populations on rocky shores. *Oikos*, **61**: 355-368.

Rai, L., Gaur, J.P. & Kumar, H.D., 1981. Phycology and heavy-metal pollution. *Biological Reviews*, **56**, 99-151.

Reed, R. H., Collins, J.C. & Russell, G., 1980. The influence of variations in salinity upon photosynthesis in the marine alga *Porphyra purpurea* (Roth) C. Ag. (Rhodophyta, Bangiales). *Z. Pflanzenphysiology*, **98**, 183-187.

Reed, R.H. & Russell, G., 1979. Adaptation to salinity stress in populations of *Enteromorpha intestinalis* (L.) Link. *Estuarine and Coastal Marine Science*, **8**, 251-258.

Ribeiro, P.A., Xavier, R., Santos, A.M. & Hawkins, S.J., 2009. Reproductive cycles of four species of *Patella* (Mollusca: Gastropoda) on the northern and central Portuguese coast. *Journal of the Marine Biological Association of the United Kingdom*, **89** (06), 1215-1221.

Rice, H., Leighty, D.A. & McLeod, G.C., 1973. The effects of some trace metals on marine phytoplankton. *CRC Critical Review in*

Microbiology, **3**, 27-49.

Robles, C., 1982. Disturbance and predation in an assemblage of herbivorous *Diptera* and algae on rocky shores. *Oecologia*, **54** (1), 23-31.

Rognstad, R.L., Wethey, D.S. & Hilbish, T.J., 2014. Connectivity and population repatriation: limitations of climate and input into the larval pool. *Marine Ecology Progress Series*, **495**, 175-183.

Say, P.J., Burrows, I.G. & Whitton, B.A., 1990. *Enteromorpha* as a monitor of heavy metals in estuaries. *Hydrobiologia*, **195**, 119-126.

Scarlett, A., Donkin, M.E., Fileman, T.W. & Donkin, P., 1997. Occurrence of the marine antifouling agent Irgarol 1051 within the Plymouth Sound locality: implications for the green macroalga *Enteromorpha intestinalis*. *Marine Pollution Bulletin*, **38**, 645-651.

Shanks, A.L. & Wright, W.G., 1986. Adding teeth to wave action- the destructive effects of wave-bourne rocks on intertidal organisms. *Oecologia*, **69** (3), 420-428.

Shepherd, S.A., Watson, J.E., Womersley, H.B.S. & Carey, J.M., 2009. Long-term changes in macroalgal assemblages after increased sedimentation and turbidity in Western Port, Victoria, Australia. *Botanica Marina*, **52** (3), 195-206.

Smith, G.M., 1947. On the reproduction of some Pacific coast species of *Ulva*. *American Journal of Botany*, **34**, 80-87.

Smith, J.E. (ed.), 1968. 'Torrey Canyon'. *Pollution and marine life.* Cambridge: Cambridge University Press.

Southward, A.J., Hawkins, S.J. & Burrows, M.T., 1995. Seventy years observations of changes in distribution and abundance of zooplankton and intertidal organisms in the western English Channel in relation to rising sea temperature. *Journal of Thermal Biology*, **20**, 127-155.

Sverdrup, H.U., Johnson, M.W. & Fleming, R.H., 1942. *The Oceans*. New York: Prentice Hall.

Tighe-Ford, D., 1967. Possible mechanism for the endocrine control of breeding in a cirripede. *Nature*, **216**, 920-921.

Tolhurst, L.E., Barry, J., Dyer, R.A. & Thomas, K.V., 2007. The effect of resuspending sediment contaminated with antifouling paint particles containing Irgarol 1051 on the marine macrophyte *Ulva intestinalis*. *Chemosphere*, **68** (8), 1519-1524.

Tyler-Walters, H. & Arnold, C., 2008. Sensitivity of Intertidal Benthic Habitats to Impacts Caused by Access to Fishing Grounds. *Report to Cyngor Cefn Gwlad Cymru / Countryside Council for Wales from the Marine Life Information Network (MarLIN) [Contract no. FC 73-03-327]*, Marine Biological Association of the UK, Plymouth, 48 pp. Available from: www.marlin.ac.uk/publications

UKTAG, 2014. UK Technical Advisory Group on the Water Framework Directive [online]. Available from: http://www.wfduk.org

Vadas, R.L., Johnson, S. & Norton, T.A., 1992. Recruitment and mortality of early post-settlement stages of benthic algae. *British Phycological Journal*, **27**, 331-351.

Vadas, R.L., Keser, M. & Rusanowski, P.C., 1976. Influence of thermal loading on the ecology of intertidal algae. In *Thermal Ecology II*, (eds. G.W. Esch & R.W. McFarlane), ERDA Symposium Series (Conf-750425, NTIS), Augusta, GA, pp. 202-212.

Vaudrey, J.M.P., Kremer, J.N., Branco, B.F. & Short, F.T., 2010. Eelgrass recovery after nutrient enrichment reversal. *Aquatic Botany*, **93** (4), 237-243.

Vermaat J.E. & Sand-Jensen, K., 1987. Survival, metabolism and growth of *Ulva lactuca* under winter conditions: a laboratory study of bottlenecks in the life cycle. *Marine Biology*, **95** (1), 55-61.

Wells, E., Best, M., Scanlan, C. & Foden, J., 2014. Opportunistic Macroalgae Blooming. Water Framework Directive- development of classification tools for ecological assessment., *Water Framework Directive-United Kingdom Technical Advisory Group (WFD-UKTAG)*,