



MarLIN

Marine Information Network

Information on the species and habitats around the coasts and sea of the British Isles

Fucus ceranoides and *Ulva* spp. on low salinity infralittoral rock

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

Frances Perry

2016-01-15

A report from:

The Marine Life Information Network, Marine Biological Association of the United Kingdom.

Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [<https://www.marlin.ac.uk/habitats/detail/283>]. All terms and the MarESA methodology are outlined on the website (<https://www.marlin.ac.uk>)

This review can be cited as:

Perry, F., 2016. [*Fucus ceranoides*] and [*Ulva*] spp. on low salinity infralittoral rock. In Tyler-Walters H. and Hiscock K. (eds) *Marine Life Information Network: Biology and Sensitivity Key Information Reviews*, [online]. Plymouth: Marine Biological Association of the United Kingdom.



The information (TEXT ONLY) provided by the Marine Life Information Network (MarLIN) is licensed under a Creative Commons Attribution-Non-Commercial-Share Alike 2.0 UK: England & Wales License. Note that images and other media featured on this page are each governed by their own terms and conditions and they may or may not be available for reuse. Permissions beyond the scope of this license are available [here](#). Based on a work at www.marlin.ac.uk

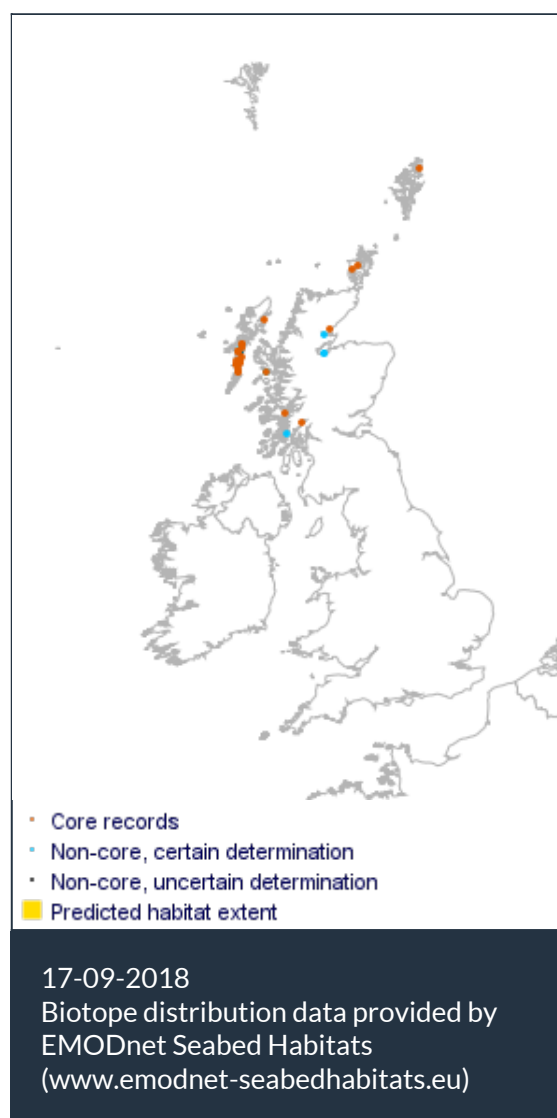
(page left blank)



Fucus ceranoides and *Enteromorpha* spp. on low salinity infralittoral rock

Photographer: Tim Hill

Copyright: Joint Nature Conservation Committee (JNCC)



Researched by Frances Perry Referred by This information is not refereed.

Summary

☰ UK and Ireland classification

EUNIS 2008	A3.344	<i>Fucus ceranoides</i> and <i>Enteromorpha</i> spp. on low salinity infralittoral rock
JNCC 2015	IR.LIR.Lag.FcerUlv	<i>Fucus ceranoides</i> and <i>Ulva</i> spp. on low salinity infralittoral rock
JNCC 2004	IR.LIR.Lag.FcerEnt	<i>Fucus ceranoides</i> and <i>Enteromorpha</i> spp. on low salinity infralittoral rock
1997 Biotope	IR.SIR.Lag.FcerEnt	<i>Fucus ceranoides</i> and <i>Enteromorpha</i> spp. on low salinity infralittoral rock

🔍 Description

Permanently submerged lagoon fringes with dense communities of wrack *Fucus ceranoides* and the green seaweed *Ulva* spp. There is typically a very limited associated biota due to low salinity conditions, and may include the opossum shrimps Mysidae and the freshwater/brackish gastropod

Potamopyrgus antipodarum. (Information from Connor *et al.*, 2004).

↓ **Depth range**

0-5 m

🏛️ **Additional information**

-

✓ **Listed By**

- none -

🔗 **Further information sources**

Search on:



Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

This biotope is characterized its presence exclusively within lagoon habitats. There are only 358 examples of these rare and unusual habitats in the UK (Bamber *et al.*, 2001), which make up a total of 5,184 hectares of coastline habitat (UKNEA, 2011). There are a number of factors which are thought to contribute to the rarity of these habitats in the UK. It is thought that many sedimentary lagoons do not appear in many of the areas suitable for them because of the macro-tidal regimes found within the north east Atlantic (Barnes, 1991). The high energy coastlines common around the UK mean that shingle lagoons can be both created from off shore glacial deposits and removed, therefore they are often short lived on geological time scales, and are now less common than they were at the end of the last ice age (Bamber *et al.*, 2001). The low energy nature of lagoons also means that they can be susceptible to silting up which can elevate their basins above the level for percolation input. Combined with perimeter shingle ridges being elevated by storms, reducing water input via overtopping, can cause lagoons to become freshwater lakes (Bamber *et al.*, 2001). The somewhat ephemeral nature of lagoons, and their susceptibility to change, means that the succession of habitats and consequently the biotopes found within them can be quicker and more noticeable than those found within other more stable physical environments.

The salinity regime within this biotope makes it suitable for *Fucus ceranoides*, a furoid whose entire life cycle is adapted to tolerate low salinities. These adaptations mean that other species of furoid can't compete within the same habitat. *Fucus ceranoides* is susceptible to high levels of grazing from littorinids to the point of their distribution being limited by them (Norton, 1986). However, the salinity conditions within this biotope mean that littorinids are not able to survive, allowing *Fucus ceranoides* to dominate. The biological community within this biotope is characteristically sparse and many of the other species have life histories which make them opportunistic, short lived and ephemeral. Such species include *Ulva lactuca* and *Ulva* (was *Enteromorpha*) *intestinalis*. The only identified grazing species come from the family Mysidae. The characterizing species identified for this biotope are the macroalgae *Fucus ceranoides* and *Ulva lactuca*, for without it the biotope would not be present. Other species contribute to the biological composition of the biotope, but are not crucial to its presence.

Resilience and recovery rates of habitat

Recolonization of *Fucus* dominated areas may take between one to three years in British waters and is especially rapid in areas cleared of grazers (Hartnoll & Hawkins, 1985; Hawkins & Hartnoll, 1985). The lack of furoid grazers is notable within this biotope. The relatively short lifespan of *Fucus ceranoides*, 3 – 5 years (Lein, 1984; Brawley, 1992a; Bäck *et al.*, 1991), and annual reproduction would allow this species to recolonize a shore quickly. If recruitment was good it is conceivable that a mature stand of *Fucus ceranoides* could be present within 3 years. Furoids don't have a planktonic dispersal stage and consequently their dispersion capacity above 50m is minimal (Chapman, 1995; Serrão *et al.*, 1997; Dudgeon *et al.*, 2001; taken from Neiva *et al.*, 2012). In addition to a low dispersal capacity *Fucus ceranoides* is found in relatively small and isolated populations in intertidal estuarine areas (Neiva *et al.*, 2012). Sperm in furoids has a greater dispersal capacity (>10m) than eggs (<0.5m) (Serrão *et al.*, 1997). Therefore, if there were to be a case of longer distance gamete fertilization within *Fucus ceranoides* it is more likely to be the sperm contributing to the gene flow (Neiva *et al.*, 2012). Yet the short lifespan, sensitivity to changes in salinity, and the effect of dilution (Serrão *et al.*, 1996) would limit the reach of *Fucus ceranoides* sperm. A mass mortality event of *Fucus ceranoides* within a lagoon due to high sensitivity to a

pressure would require the long distance transport of drifting fertile fronds (Neiva *et al.*, 2012). The frequency of such events must be low. However, Neiva *et al.*, (2012) deduced that this must have been the only mechanism via which *Fucus ceranoides* was able to recolonize northern Europe since the last ice age. There are no documented examples of this but it is reasonable to assume that the frequency of a successful relocation to a new habitat location is low.

Unlike many communities, the community structure within this biotope does not appear to be greatly altered by a grazing species. *Littorina littorea* is a dominant grazer on many rocky intertidal and subtidal habitats where salinity regimes are either full (30 – 40 psu) or variable (18 – 40 psu) (Connor *et al.*, 2004). However, in lab experiments *Littorina littorea* grazing activity is significantly reduced below salinities of 17‰ (Norton, 1986). In the Firth of Clyde the seaward limit of *Fucus ceranoides* coincides with the inland limit of littorinids (Norton, 1986). In the field *Littorina littorea* is replaced by amphipods as the dominant mesograzer when salinities regularly fall below 12‰ (Johannesson *et al.*, 1988). The main grazers present within this biotope are Mysids. These crustaceans are from the same superorder as Amphipods. Mysids are similar to Amphipods in their feeding habits, and it is likely that fill the functional niche that Amphipods do within the LR.LLR.FVS.Fcer biotope. In both the biotope being considered within this review and LR.LLR.FVS.Fcer these grazing crustaceans are presumably present because the reduced to low salinity regimes are not suitable for Littorinids. Among other things Mysids consume macroalgae. Macroalgae has been found to contribute as much as 68% of the total diet of a species of Mysid (Kibirige *et al.*, 2003). This consumption could have a strong impact on the weight of macroalgae and the structuring of the biotope in question. However, strong predation on amphipods within a *Fucus vesiculosus* habitat found that macroalgae biomass did not change (Eriksson *et al.*, 2011). This was due to omnivorous shrimps grazing the macroalgae when their main food source i.e. the amphipods were removed. Thus preventing a trophic cascade and a change in biotope. Within this biotope mysids appear to be the dominant grazing species. Predicting how species, such as omnivorous shrimps, may indirectly affect this biotope when immersed is difficult because these species are not considered in intertidal biotopes. No evidence can be found on the impact of mysid grazing on the characterizing species, *Fucus ceranoides* and *Ulva* sp.. This lack of evidence, combined with the comparatively low 'typical abundance' and '% contribution to similarity' between the core records of this biotope means that Mysids have not been included as a characterizing species within this biotope assessment. However, any pressure which may cause significant changes in the abundance in mysids and could have a negative impact on the biotope will be taken into consideration when assessing the effects of pressures. Mysids are associated with a number of ephemeral intertidal biotopes such as SS.SSa.SSaVS (Connor *et al.*, 2004). Many species of mysids have short life histories, and will be able quickly repopulate an area (Fish & Fish, 1996).

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

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

Hydrological Pressures

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

Populations of *Fucus ceranoides* are restricted to low salinity environments such as estuaries and saline lagoons. However, examples of this biotope are found throughout the British Isles. The distribution of *Fucus ceranoides* in the north east Atlantic extends from northern Norway (Lein, 1984) to the River Mondego in Portugal (Neiva *et al.*, 2012). Although species ranges may not accurately describe their ability to withstand localized changes in temperature. They may to some extent display the limits of the species genetic ability to acclimatize to temperatures. Growth rates in *Fucus ceranoides* have not been recorded, and there is no empirical evidence on the upper and lower temperature tolerances. This biotope is occasionally found on the low shore (17.65%) but is almost as common on the upper shore (52.94%) as it is on the mid shore (47.06%) (Connor *et al.*, 2004; physical comparative tables). This range in location on the shore suggests that *Fucus ceranoides* can tolerate a range of temperatures. Fertilization at extreme high (25 °C) temperatures can only occur in full salinity (Burrows, 1964).

Ulva sp. are distributed globally (Guiry & Guiry, 2015) and occur in warmer waters than those surrounding the UK suggesting that they can withstand increases in temperature at the pressure benchmark. *Ulva* sp. are characteristic of upper shore rock pools, where water and air temperatures are greatly elevated on hot days. Empirical evidence for thermal tolerance to anthropogenic increases in temperature is provided by the effects of heated effluents on rocky shore communities in Maine, USA. *Ascophyllum* and *Fucus* were eliminated from a rocky shore

heated to 27-30 °C by a power station whilst *Ulva intestinalis* (as *Enteromorpha intestinalis*) increased significantly near the outfall (Vadas *et al.*, 1976).

Sensitivity assessment. An increase in temperature at the pressure benchmark may cause some *Fucus ceranoides* to die off at the top of the shore due to increased levels of desiccation caused by higher temperatures, especially during the summer months. However, it will not cause large losses of the characterizing species. *Ulva* sp. are resistant to high temperatures and are very quick to recolonize. Both resistance and resilience have been assessed as 'High', meaning the biotope is 'Not sensitive' to an increase in temperature at the pressure benchmark.

Temperature decrease (local)

Low

Q: High A: High C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

Populations of *Fucus ceranoides* are restricted to low salinity environments such as estuaries and saline lagoons. The distribution of *Fucus ceranoides* in the north east Atlantic extends from northern Norway (Lein, 1984) to the River Mondego in Portugal (Neiva *et al.*, 2012). Although species ranges may not accurately describe their ability to withstand localized changes in temperature. They may to some extent display the limits of the species genetic ability to acclimatize to temperatures. Growth rates in *Fucus ceranoides* have not been recorded, and there is no empirical evidence on the upper and lower temperature tolerances. This biotope is occasionally found on the low shore (17.65%) but is almost as common on the upper shore (52.94%) as it is on the mid shore (47.06%) (Connor *et al.*, 2004; physical comparative tables). This range in location on the shore suggests that *Fucus ceranoides* can tolerate a range of temperatures. Fertilization at extreme low (2 °C) temperatures can only occur in full salinity (Burrows, 1964). At a water temperature of 10 °C, fertilization is entirely inhibited below 8 ppt (Burrows, 1964).

Ulva intestinalis and *Ulva lactuca*, occur in Arctic regions and Alaska and are therefore found in colder waters than those around the UK (Guiry & Guiry, 2015), *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).

Sensitivity assessment. A decrease in temperature at the pressure benchmark is not likely to have a significant effect on *Fucus ceranoides*. There may be some decrease in growth rate, and a greater effect of winter temperatures. However, it will not cause large die backs of the characterizing species. *Ulva* sp. are resistant to low temperatures and are very quick to recolonize. Both resistance and resilience have been assessed as 'High', meaning the biotope is 'Not sensitive' to an increase in temperature at the pressure benchmark.

Salinity increase (local)

Low

Q: High A: High C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

Fucus ceranoides can grow and become fertile between salinities of 7 – 34 ppt (Burrows, 1964). Its optimal salinity for growth rate is 16 ppt, however successful fertilization occurs most commonly at high salinities (Burrows, 1964). The eggs of *Fucus ceranoides* can tolerate immersion in freshwater within 2 hours of release (Burrows, 1964). Germlings and excised tips of *Fucus ceranoides* develop tissue damage and decay in full salinity water (Khfaji & Norton, 1979). If *Fucus*

ceranoides is subject to fully marine conditions it decays within a few months (Khfaji & Norton, 1979; Suryono & Hardy, 1997). The evidence suggests that the fluctuation in salinity is important to the survival of *Fucus ceranoides*. And even if *Fucus ceranoides* was able to tolerate fully marine conditions it is unlikely to survive as it grows slower than other fucoids such as *Fucus vesiculosus* (Khfaji & Norton, 1979) and would be out-competed for space. An increase in the salinity regime would also mean that the habitat would become suitable for species of littorinids, a species which has a significant negative impact through on *Fucus ceranoides* through grazing (Norton, 1986).

Ulva sp. can survive hypersaline conditions in supralittoral rock pools 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. Alström-Rapaport *et al.* (2010), found that in the brackish Baltic Sea, *Ulva intestinalis* uses a variety of reproductive modes which partly explained the high rates of colonization 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 a decreased percentage of regeneration in concentrated seawater; i.e. 51, 68, 95, 102 & 136 psu when compared to littoral fringe populations of *Ulva intestinalis* (as *Enteromorpha intestinalis*).

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

Salinity decrease (local)

Medium

Q: High A: High C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

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

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

colonization 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 a decreased percentage of regeneration in all salinities (0, 4.25, 8.5, 17 & 25.5, 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.

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

Water flow (tidal current) changes (local)

High

Q: Medium A: Medium C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: Medium A: Medium C: Medium

This biotope is found in very weak tidal conditions. However, the characterizing species *Fucus ceranoides* is limited to the salinity regimes found within estuaries and saline lagoons, environments which also happen to have these water flow conditions. An increase in water flow at the benchmark is unlikely to have a significant negative effect on the biological composition of the biotope. However, it must be assumed that if there is an increase in the water flow within the biotope there will also be an increase in the water flow around the lagoon. An increase in the water flow at the pressure benchmark is very unlikely to have a detrimental effect on the structure of the lagoon through erosion. However, if there was an increase in water flow above the level of the benchmark this could consequently lead to the loss collapse of a lagoon wall and completely change the physical environment of the biotope, and lead to the loss of the lagoon biotope altogether.

No empirical evidence is available on water flow tolerances in *Fucus ceranoides*. An investigation into *Fucus spiralis* (a species whose fronds reach a maximum length comparable to that of *Fucus ceranoides*) found that plants were torn from their holdfast at 7 – 8 m/sec (Jonsson *et al.*, 2006). Even if water flows an increase in water flow didn't directly remove adults from the substrata, it could have an impact on dispersal, fertilization, settlement and recruitment (Pearson & Brawley, 1996).

Both *Ulva intestinalis* and *Ulva lactuca* are flexible and conform to the direction of the flow reducing drag and breakage. However, experimental studies show that exposure to currents results in sloughing of tissue and higher current velocities result in breakage of the thallus. Kennison & Fong (2013) found that *Ulva intestinalis*, settled on ceramic tiles and deployed in the field were subject to greater losses at mean flow speeds of 0.2 m/s (approximately 16% of biomass) than the 8% loss from individuals subject to lower flows (0.15 m/s).

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 swimmers 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: At the level of the benchmark a change in water flow are likely to have an impact on either the biological communities or physical environment of this biotope. Consequently, both resistance and resilience have been assessed as 'High', resulting in an overall sensitivity of 'Not Sensitive'.

Emergence regime changes

Low

Q: Medium A: Medium C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

Emergence regime is a key factor structuring this (and other) intertidal biotopes. *Fucus ceranoides* can be found from the upper intertidal, down to the lower shore, where it is least common (Connor *et al.*, 2004; Physical comparative tables). A change in emergence would lead to a shift in the area covered by *Fucus ceranoides* and this biotope.

Ulva sp. lose their water content very fast, but overcome the problem by growing in dense populations where they can cover and shade each other to some extent when exposed. As *Ulva intestinalis* is able to tolerate desiccation 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. 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.

Sensitivity assessment. A change in emergence would lead to a loss of the biotope at its upper and lower extent due to the physical factors becoming too severe for the organisms to cope with. The salinity regime within this biotope means that there are a restricted number of species which are able to survive and reproduce within the conditions. Consequently a change in emergence would not necessarily allow other species to become more abundant. The resistance to a change in emergence is at the limits of this biotope is 'Low' and resilience is 'Medium', giving a sensitivity of 'Medium'.

Wave exposure changes (local)**High**

Q: High A: High C: High

High

Q: High A: High C: High

Not sensitive

Q: High A: High C: High

This biotope is found in extremely sheltered conditions. However, the characterizing species *Fucus ceranoides* is limited to the salinity regimes found within estuaries and saline lagoons; environments which also happen to have these wave exposures. Therefore, wave exposures experienced within the biotope may only be a factor of the physical environment and not a limiting factor for the biological species.

No empirical evidence is available on wave exposure tolerances in *Fucus ceranoides* and *Ulva* spp. However, both species can be found in biotopes which have water flows in excess of moderately strong (Connor *et al.*, 2004). This suggests that an increase in wave exposure would not have a negative impact on the characterizing species. The remaining species within this biotope are found within other biotopes where wave exposure exceeds that found within this biotope.

An increase in wave exposure at the benchmark is unlikely to have a significant negative effect on the biological composition of the biotope. However, it might be assumed that if there is an increase in the wave height within the biotope there will also be an increase in the water flow around the lagoon. This increase could have a detrimental effect on the structure of the lagoon through erosion. This could consequently lead to the loss collapse of a lagoon wall and completely change the physical environment of the biotope, and lead to the loss of the lagoon biotope altogether.

Sensitivity assessment. Wave exposure can have a significant impact on the health of biotopes and can directly impact on the abundance of species. However, at the benchmark of this pressure resistance and resilience are assessed as 'High' which gives the biotope an assessment of 'Not Sensitive'.

🧪 Chemical Pressures**Resistance****Resilience****Sensitivity****Transition elements & organo-metal contamination**

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

Hydrocarbon & PAH contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

Synthetic compound contamination

Not Assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

Not assessed (NA)

Q: NR A: NR C: NR

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

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

No evidence.

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

This pressure is **Not assessed**.

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

Cole *et al.* (1999) suggested possible adverse effects on marine species below oxygen levels of 4 mg/l and probable adverse effects below 2 mg/l. Sustained reduction of dissolved oxygen can lead to hypoxic (reduced dissolved oxygen) and anoxic (extremely low or no dissolved oxygen) conditions. Continued or repeated episodes of reduced dissolved oxygen have the potential to severely degrade an ecosystem (Cole *et al.*, 1999).

Reduced oxygen concentrations have been shown to inhibit both photosynthesis and respiration in macroalgae (Kinne, 1977). Despite this, macroalgae are thought to buffer the environmental conditions of low oxygen, thereby acting as a refuge for organisms in oxygen depleted regions especially if the oxygen depletion is short-term (Frieder *et al.*, 2012). If levels do drop below 4 mg/l negative effects on these organisms can be expected with adverse effects occurring below 2mg/l (Cole *et al.*, 1999). Reduced oxygen levels are likely to inhibit photosynthesis and respiration but not cause a loss of the macroalgae population directly.

Vermaat & Sand-Jensen (1987) tested the survival of discs of *Ulva lactuca* during prolonged exposure to anoxia. The 113 mm² 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 N₂ gas. Exposure to anoxia for two months did not affect survival but did result in increased respiration and decreased growth. Corradi *et al.* (2006) used similar sized thallus discs from *Ulva* spp. (113 mm²), 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.

The biotope in question occurs in the eulittoral and consequently a proportion of time will be spent in air where oxygen is not limited so the metabolic processes of photosynthesis and respiration can take place. This biotope is found in extremely wave sheltered conditions and the moderately strong to negligible tidal flows, consequently water mixing is not very strong. Therefore water movement within this area will not reverse any oxygen depletion quickly, possibly exacerbating any negative effects.

Sensitivity assessment. The characterizing species *Fucus ceranoides* and *Ulva* spp. require oxygen for respiration. The intertidal position of this biotope means that all species spend periods of time emersed, where oxygen is not limited. This is advantageous for algae and can allow them to continue to photosynthesis and respire. Both resistance and resilience are assessed as 'High', giving the biotope a sensitivity score of 'Not sensitive'.

Nutrient enrichment**High**

Q: High A: High C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: High A: Medium C: Medium

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

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

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

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 47 papers reviewed relating to nutrients as a contaminants, over 75% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. None of the 47 papers considered the impact of nutrients on saline lagoons. Yet this finding is likely to still be relevant as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of nutrient enrichment from these sources on intertidal rocky shores (none of these intertidal shores were within lagoons) often lead to shores lacking species diversity and the domination by algae with fast growth rates (Littler & Murray, 1975; Abou-Aisha *et al.*, 1995; Archambault *et al.*, 2001; Diez *et al.*, 2003; Arévalo *et al.*, 2007;).

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

increase algae abundance, but the abundance of grazing species (Kraufvelin, 2007).

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

Sensitivity assessment. A slight increase in nutrients may enhance growth rates but high nutrient concentrations could lead to the overgrowth of the algae by ephemeral green algae and an increase in the number of grazers. However, if the biotope is well established and in a healthy state the biotope could have the potential to persist. The effect of an increase in this pressure to the benchmark level should not have a negative impact on the biotope. Therefore the resistance has been assessed as 'High', resulting in a sensitivity of 'Not Sensitive'.

Organic enrichment

Medium

Q: Medium A: Low C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Low C: Medium

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

Johnston & Roberts (2009) undertook a review and meta analysis of the effect of contaminants on species richness and evenness in the marine environment. Of the 49 papers reviewed relating to sewage as a contaminant, over 70% found that it had a negative impact on species diversity, <5% found increased diversity, and the remaining papers finding no detectable effect. None of the 49 papers considered the impact of sewage on saline lagoons. Yet this finding is likely to still be relevant as the meta analysis revealed that the effect of marine pollutants on species diversity were 'remarkably consistent' between habitats (Johnston & Roberts, 2009). It was found that any single pollutant reduced species richness by 30-50% within any of the marine habitats considered (Johnston & Roberts, 2009). Throughout their investigation there were only a few examples where species richness was increased due to the anthropogenic introduction of a contaminant. These examples were almost entirely from the introduction of nutrients, either from aquaculture or sewage outfalls. However, research into the impacts of organic enrichment from these sources on intertidal rocky shores often lead to shores lacking species diversity and the domination by algae with fast growth rates (Abou-Aisha *et al.*, 1995, Archambault *et al.*, 2001, Arévalo *et al.*, 2007, Diez *et al.*, 2003, Littler & Murray, 1975).

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

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

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

Sensitivity assessment. Little empirical evidence was found to support an assessment of this biotope at this benchmark. The contribution of *Ulva* sp. to the biological community within this biotope means that if conditions were to become more favourable for this species it could easily increase in abundance. An increase in this species could over grow the slower growing characterizing species *Fucus ceranoides*. Due to the potential negative impacts that have been reported to result from the introduction of excess organic carbon, resistance has been assessed as 'Medium' and resilience has been assessed as 'Medium'. This gives an overall sensitivity score of 'Medium'.

A 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 is characterized by a lagoon formed from bedrock, boulders and cobbles. Removal of this substratum would remove the attachment surface for the macroalgae that characterize this biotope, significantly altering the character of the biotope. Artificial hard substratum may also differ in character from natural hard substratum, so that replacement of natural surfaces with artificial may lead to changes in the biotope through changes in species composition, richness and diversity (Green *et al.*, 2012; Firth *et al.*, 2014) or the presence of non-native species (Bulleri & Airoldi, 2005).

The change in substratum also has the potential to de-stabilize the lagoon structure. This change in structure could make the lagoon more susceptible to erosion from other physical factors at work within the environment.

Sensitivity assessment. A change in substratum would result in the loss of the characterizing species *Fucus ceranoides* and *Ulva* sp. along with other species associated with this biotope.

Resistance is assessed as 'None'. As this pressure represents a permanent change, recovery is impossible as the suitable substratum for the biological community of this biotope is lacking. Consequently, resilience is assessed as 'Very Low'. The habitat, therefore, scores a 'High' sensitivity. Although no specific evidence is described confidence in this assessment is 'High', due to the incontrovertible nature of this pressure.

Physical change (to another sediment type)

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

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

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

Not Relevant for bedrock biotopes.

Habitat structure changes - removal of substratum (extraction)

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

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

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

The species characterizing this biotope occur on rock and would be sensitive to the removal of the habitat. However, extraction of rock substratum is considered unlikely and this pressure is considered to be 'Not relevant' to hard substratum habitats.

Abrasion/disturbance of the surface of the substratum or seabed

Low
Q: High A: Medium C: Medium

Medium
Q: High A: High C: Medium

Medium
Q: High A: Medium C: Medium

No studies of the effects of trampling or netting on lagoons were found but studies of the effects on emergent algal communities are probably indicative. Trampling on the rocky shore has been observed to reduce furoid cover, which decreased the microhabitat available for epiphytic species, increased bare space and increased cover of opportunistic species such as *Ulva* (Fletcher & Frid, 1996a). The location of this biotope within a saline lagoon means that the area is easily accessible by humans especially at low tide. Individual microalgae's are flexible but not physically robust, Fucoids are intolerant of abrasion from human trampling, and has been shown to reduce the cover of seaweeds on a shore (Holt *et al.*, 1997).

Brosnan (1993) suggested that the presence or absence of foliose algae (e.g. fucoids) could be used to indicate the level of trampling on the rocky shores of Oregon. In the UK, Boalch *et al.* (1974) and Boalch & Jephson (1981) noted a reduction in the cover of fucoids at Wembury, south Devon, when compared to surveys conducted by Colman (1933). The size ranges of *Ascophyllum nodosum*, *Fucus vesiculosus* and *Fucus serratus* were skewed to a smaller length, and the abundance of *Ascophyllum nodosum*, in particular, was reduced (Boalch & Jephson, 1981). It was suggested that visitor pressure, especially after the construction of a car park, was responsible for the reduced cover of fucoids (Boalch *et al.*, 1974). They suggested that the raised edges of the slatey rock, severed fronds when the rocks were walked over. However, no quantitative data was provided. Conversely, algal turfs seem to be relatively tolerant of the direct effects of trampling (based on the available evidence) and some species may benefit from the removal of canopy-forming algae (Tyler-Walters, 2005). Their tolerance may result from their growth form as has been shown for vascular plants and corals (Liddle, 1997). Brosnan (1993) suggested that algal turf dominated areas (on shores usually dominated by fucoids) were indicative of trampling on the rocky shores of Oregon. However, tolerance is likely to vary with species and their growth form and little species specific data was found. Furthermore, algal turfs may suffer negative indirect

effects where they form an understory below canopy forming species.

Pinn & Rodgers (2005) compared a heavily visited ledge with a less visited ledge at Kimmeridge Bay, Dorset. Although the mean species richness was similar at both sites, the total number of species was greater at the less utilized site. Comparatively, the heavily utilized ledge displayed a reduction in larger, branching algal species (e.g. *Fucus serratus*) and increased abundances of ephemeral and crustose species (e.g. *Ulva linza* and *Lithothamnium* spp. respectively). Fletcher & Frid (1996a; b) examined the effects of persistent trampling on two sites on the north-east coast of England. The trampling treatments used were 0, 20, 80, and 160 steps per m² per spring tide for 8 months between March and November. Using multivariate analysis, they noted that changes in the community dominated by furoids (*Fucus vesiculosus*, *Fucus spiralis* and *Fucus serratus*) could be detected within 1 to 4 months of trampling, depending on intensity. Intensive trampling (160 steps/m² /spring tide) resulted in a decrease in species richness at one site. The area of bare substratum also increased within the first two months of trampling but declined afterwards, although bare space was consistently most abundant in plots subject to the greatest trampling (Fletcher & Frid, 1996a; b). The abundance of furoids was consistently lower in trampled plots than in untrampled plots.

Fletcher & Frid (1996a; b) also reported a decrease in the understory algal community of encrusting coralline algae and red algae, which was probably an indirect effect due to increased desiccation after removal of the normally protective furoid canopy (see Hawkins & Harkin, 1985) by trampling. They also noted that opportunistic algae (e.g. *Ulva* sp.) increased in abundance. Fletcher and Frid (1996a) noted that the species composition of the algal community was changed by as little as 20 steps per m² per spring tide of continuous trampling since recolonization could not occur. A trampling intensity of 20 steps per m² per spring tide could be exceeded by only five visitors taking the same route out and back again across the rocky shore in each spring tide. Both of the sites studied receive hundreds of visitors per year and damage is generally visible as existing pathways, which are sustained by continuous use (Fletcher & Frid, 1996a; b). However, the impact was greatest at the site with the lower original abundance of furoids.

Sensitivity assessment. The impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Lagoons form natural shallow water mesocosms and can attract considerable attention from the general public, educational events and scientists alike. All of whom can cause abrasion damage to the species within the biotope. Abrasion of the substratum will cause a reduction in the abundances of both characterizing species, as well as other species found in the associated community. The resistance to this pressure at the benchmark level is 'Low'. The resilience is 'Medium', giving a sensitivity of 'Medium'.

Penetration or disturbance of the substratum subsurface

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Changes in suspended solids (water clarity)

High

Q: High A: Medium C: Medium

High

Q: High A: Medium C: Medium

Not sensitive

Q: High A: Medium C: Medium

In general, increased suspended particles may enhance food supply (where these are organic in origin) or decrease feeding efficiency (where the particles are inorganic and require greater filtration efforts). Very high levels of silt may clog respiratory and feeding organs of the suspension feeding barnacle species. In addition, increased turbidity will decrease light penetration reducing photosynthesis by macroalgae within this biotope. *Fucus ceranoides* is found within all zones of intertidal rocky shores. Water depths within this part of the intertidal will never be great. So although an increase in turbidity at this pressure benchmark will increase light attenuation it is likely that light will still penetrate to the depth at which the algae are found. Those examples of *Fucus ceranoides* found on the lower shore may be mildly affected by this and may experience a slight decrease in growth rate, however, there is no empirical evidence for this. A decrease in SPM could be unlikely to have a negative impact on the macroalgae within this biotope. Increased levels of particles may increase scour and deposition in the biotope depending on local hydrodynamic conditions, although changes in substratum are assessed through the physical change (to another seabed type) pressure.

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

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

Smothering and siltation rate changes (light)

Medium

Q: High A: Medium C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: High A: Medium C: Medium

A discrete event where sediment inundates this biotope to 5 cm will have different effects on the characterizing species depending on the state of the tide. During high tide, the characterizing species will be vertical in the water column. Any deposition at this state of the tide will mean that only a proportion of the stipe and holdfast will be covered. Fronds of *Fucus ceranoides* are 30 – 60 cm in length (Bunker *et al.*, 2012). Consequently, sediment deposition at high tide could leave a proportion of *Fucus ceranoides* fronds sediment free. In contrast, if the tide is out then fronds of the characterizing furoid canopy will be flat on the substratum and will be smothered by the sediment deposit. There is no empirical evidence to suggest how smothering affects *Fucus ceranoides*. However, it may be assumed that inundation with sediment will reduce gaseous exchange limiting the macroalgae ability to photosynthesize and respire. Without the ability to carry out these two functions fronds will become damaged and consequently die. Moderately strong water flows caused by tidal movements within this biotope could remove sediment from the shore within a few tidal cycles. Germlings are likely to be smothered and killed regardless of the state of the tide and are inherently most susceptible to this pressure. Indeed early life stages are smaller in size than adults and are thus most vulnerable to this pressure as even a small load of added sediment will lead to the complete burial. Sediment deposition can reduce macroalgal recruitment by (1) reducing the amount of substratum available for attachment of propagules; (2) scour, removing attached juveniles and (3) burial, altering the light and/or the chemical microenvironment (Devlin & Volse, 1978, Eriksson & Johansson, 2003).

Observations and experiments indicate that *Ulva* spp. have relatively high tolerances for the stresses induced by burial (darkness, hypoxia and exposure to sulphides). Vermaat & Sand-Jensen, (1987) exposed thallus discs (113 mm²) 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 $\mu\text{mol/L}$, or sulphide at 1mM, both treatments in darkness) for 3, 5 or 7 days 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* sp. in sheltered areas are often unattached to the substratum and therefore are not considered a direct proxy for attached *Ulva* sp. in this biotope.

Although *Ulva* sp. present in sedimentary habitats may be able to survive the chemical stress of burial and re-grow from surviving fragments, evidence for attached individuals from rocky shores suggests that resistance to this pressure may be lower. *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 colonize sand-scoured areas (such as this biotope). *Ulva* sp. have, however, been reported to form turfs that trap sediments (Airoldi, 2003) 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 North East 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.

Another consideration for this biotope is the effect that sedimentation may have on the physical aspect of the lagoon. If saline lagoons become silted up then the basin can be raised above percolation input, causing the lagoon to become a freshwater lake (Bamber *et al.*, 2001). Each lagoon will respond differently to 5 cm of sediment inundation and there is no evidence to suggest how different lagoons might respond.

Sensitivity assessment. Within this biotope water flow is negligible (Connor *et al.*, 2004). This lack of water movement will result in the deposited sediment remaining within the lagoon for an extended period of time. Sediment will be present long enough to cause damage to the fronds of *Fucus ceranoides* and the other species within this biotope. For this reason, resistance and resilience have been assessed as 'Medium', giving the biotope of a sensitivity of 'Medium'.

Smothering and siltation rate changes (heavy)

Low

Q: NR A: NR C: NR

Medium

Q: High A: Medium C: Medium

Medium

Q: Low A: Low C: Low

A deposit at the pressure benchmark would cover all species with a thick layer of fine materials. Species associated with this biotope such as littorinids would not be able to escape and would likely suffer mortality (see evidence for light siltation). Sensitivity to this pressure will be mediated

by site-specific hydrodynamic conditions and the footprint of the impact. Where a large area is covered sediments may be shifted by water currents rather than removed. Mortality will depend on the duration of smothering; where wave action rapidly mobilises and removes fine sediments, survival of the characterizing and associated species may be much greater.

Sensitivity assessment. The resistance to this pressure at the benchmark is 'Low', and the resilience is 'Medium', which results in a sensitivity assessment of 'Medium'.

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

Not assessed.

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

No evidence.

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

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

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

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

A number of experiments have demonstrated that *Ulva lactuca*, has a 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 113 mm²) to continue to grow at the lowest irradiance tested (0.6 $\mu\text{E m}^2/\text{s}$). 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).

Sensitivity assessment. It is not clear how these findings may reflect changes in light levels from artificial sources, and whether observable changes would occur at the population level as a result. There is, therefore, 'No evidence' on which to base an assessment.

Barrier to species movement

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant – this pressure is considered applicable to mobile species, e.g. fish and marine mammals rather than seabed habitats. Physical and hydrographic barriers may limit propagule dispersal. But propagule dispersal is not considered under the pressure definition and benchmark.

Death or injury by collision

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Visual disturbance

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant.

 **Biological Pressures**

Resistance

Resilience

Sensitivity

Genetic modification & translocation of indigenous species

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

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

Introduction or spread of invasive non-indigenous species

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

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

Introduction of microbial pathogens

No evidence (NEv)

Q: NR A: NR C: NR

Not relevant (NR)

Q: NR A: NR C: NR

No evidence (NEv)

Q: NR A: NR C: NR

There is insufficient evidence to support a review of the pressure at this benchmark. No evidence is available on the microbes that are associated with the characterizing species *Fucus ceranoides* or *Ulva* sp. Barnacles are considered subject to persistent, low levels of infection by pathogens and parasites. But little specific information on the effects they have on their hosts is available.

Sensitivity assessment. Due to the lack of information on the effect of microbial pathogens on the

species found within this biotope an assessment of 'No evidence' has been given.

Removal of target species

Low

Q: Medium A: Medium C: Medium

Medium

Q: High A: Medium C: Medium

Medium

Q: Medium A: Medium C: Medium

Direct, physical impacts from harvesting are assessed through the abrasion and penetration of the seabed pressures. The sensitivity assessment for this pressure considers any biological/ecological effects resulting from the removal of target species on this biotope. There is a lack of evidence for the intertidal collection of *Fucus ceranoides*. Many intertidal microalgae are harvested from the shore for both commercial and recreational purposes. The easy intertidal access to this species means that it would be easily collected from a shore. As the key characterizing and structuring species, extensive removal of *Fucus ceranoides* would alter the character of the biotope. *Ulva* sp. are occasionally harvested for commercial and personal use. The highly ephemeral nature of these species and their ability to grow back very quickly means that that harvesting is unlikely to have a big negative impact on the biotope as a whole.

Sensitivity assessment. The resistance of both *Fucus ceranoides* and *Ulva* sp. to removal is 'Low'. The resilience of the biotope is 'Medium'. Consequently the biotope sensitivity is assessed as 'Medium'.

Removal of non-target species

Low

Q: Medium A: Medium C: Medium

Medium

Q: Medium A: High C: Medium

Medium

Q: Medium A: Medium C: Medium

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

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

Bibliography

- Serrão, E.A., Kautsky, L. & Brawley, S.H., 1996. Distributional success of the marine seaweed *Fucus vesiculosus* L. in the brackish Baltic Sea correlates with osmotic capabilities of Baltic gametes. *Oecologia*, **107** (1), 1-12.
- 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.
- Aguilera, J., Karsten, U., Lippert, H., Voegelé, B., Philipp, E., Hanelt, D. & Wiencke, C., 1999. Effects of solar radiation on growth, photosynthesis and respiration of marine macroalgae from the Arctic. *Marine Ecology Progress Series*, **191**, 109-119.
- Airoidi, L., 2003. The effects of sedimentation on rocky coast assemblages. *Oceanography and Marine Biology: An Annual Review*, **41**, 161-236
- Alström-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.
- Arévalo, R., Pinedo, S. & Ballesteros, E., 2007. Changes in the composition and structure of Mediterranean rocky-shore communities following a gradient of nutrient enrichment: descriptive study and test of proposed methods to assess water quality regarding macroalgae. *Marine Pollution Bulletin*, **55** (1), 104-113.
- Archambault, P., Banwell, K. & Underwood, A., 2001. Temporal variation in the structure of intertidal assemblages following the removal of sewage. *Marine Ecology Progress Series*, **222**, 51-62.
- Bäck, S., Collins, J.C. & Russell, G., 1991. Aspects of the reproductive biology of *Fucus vesiculosus* from the coast of south west Finland. *Ophelia*, **34**, 129-141.
- Bamber, R.N., Gilliland, P.M. & Shardlow, M.E.A., 2001. *Saline lagoons: a guide to their management and creation* (interim version). Peterborough: English Nature.
- Barnes, R.S.K., 1991. Dilemmas in the theory and practice of biological conservation as exemplified by British coastal lagoons. *Biological Conservation*, **55**, 315 - 323.
- Berger, R., Bergström, L., Granéli, E. & Kautsky, L., 2004. How does eutrophication affect different life stages of *Fucus vesiculosus* in the Baltic Sea? - a conceptual model. *Hydrobiologia*, **514** (1-3), 243-248.
- Boalch, G.T. & Jephson, N.A., 1981. A re-examination of the seaweeds on Colman's traverses at Wembury. *Proceedings of the International Seaweed Symposium*, **8**, 290-293.
- Boalch, G.T., Holme, N.A., Jephson, N.A. & Sidwell, J.M.C., 1974. A resurvey of Colman's intertidal traverses at Wembury, South Devon. *Journal of the Marine Biological Association of the United Kingdom*, **5**, 551-553.
- Bokn, T.L., Duarte, C.M., Pedersen, M.F., Marba, N., Moy, F.E., Barrón, C., Bjerkgeng, B., Borum, J., Christie, H. & Engelbert, S., 2003. The response of experimental rocky shore communities to nutrient additions. *Ecosystems*, **6** (6), 577-594.
- Bokn, T.L., Moy, F.E., Christie, H., Engelbert, S., Karez, R., Kersting, K., Kraufvelin, P., Lindblad, C., Marba, N. & Pedersen, M.F., 2002. Are rocky shore ecosystems affected by nutrient-enriched seawater? Some preliminary results from a mesocosm experiment. *Sustainable Increase of Marine Harvesting: Fundamental Mechanisms and New Concepts*: Springer, pp. 167-175.
- Brawley, S.H., 1992a. Fertilization in natural populations of the dioecious brown alga *Fucus ceranoides* and the importance of the polyspermy block. *Marine Biology*, **113** (1), 145-157.
- Bricker, S.B., Clement, C.G., Pirhalla, D.E., Orlando, S.P. & Farrow, D.R., 1999. National estuarine eutrophication assessment: effects of nutrient enrichment in the nation's estuaries. NOAA, National Ocean Service, Special Projects Office and the National Centers for Coastal Ocean Science, Silver Spring, MD, 71 pp.
- Bricker, S.B., Longstaff, B., Dennison, W., Jones, A., Boicourt, K., Wicks, C. & Woerner, J., 2008. Effects of nutrient enrichment in the nation's estuaries: a decade of change. *Harmful Algae*, **8** (1), 21-32.
- Brosnan, D.M., 1993. The effect of human trampling on biodiversity of rocky shores: monitoring and management strategies. *Recent Advances in Marine Science and Technology*, **1992**, 333-341.
- Bulleri, F. & Airoidi, L., 2005. Artificial marine structures facilitate the spread of a non-indigenous green alga, *Codium fragile* ssp. *tomentosoides*, in the north Adriatic Sea. *Journal of Applied Ecology*, **42** (6), 1063-1072.
- Bunker, F., Maggs, C., Brodie, J. & Bunker, A., 2012. *Seasearch Guide to Seaweeds of Britain and Ireland*. Marine Conservation Society, Ross-on-Wye.
- Burrows, E.M., 1964. Ecological experiments with *Fucus*. *Proceedings of the International Seaweed Symposium*, **4**, 166 - 170.
- Chapman, A.R.O. (1995). Functional ecology of furoid algae: twenty-three years of progress. *Phycologia*, **34**(1), 1-32.
- Cole, S., Codling, I.D., Parr, W., Zabel, T., 1999. Guidelines for managing water quality impacts within UK European marine sites [On-line]. *UK Marine SACs Project*. [Cited 26/01/16]. Available from: http://www.ukmarinesac.org.uk/pdfs/water_quality.pdf
- Colman, J., 1933. The nature of the intertidal zonation of plants and animals. *Journal of the Marine Biological Association of the United Kingdom*, **18**, 435-476.
- 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. Joint Nature Conservation Committee, Peterborough. www.jncc.gov.uk/MarineHabitatClassification.
- Corradi, M.G., Gorbi, G. & Zanni, C., 2006. Hypoxia and sulphide influence gamete production in *Ulva* sp. *Aquatic Botany*, **84** (2), 144-150.
- 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.
- Devinny, J. & Volse, L., 1978. Effects of sediments on the development of *Macrocystis pyrifera* gametophytes. *Marine Biology*, **48** (4), 343-348.
- Diez, I., Santolaria, A. & Gorostiaga, J., 2003. The relationship of environmental factors to the structure and distribution of subtidal seaweed vegetation of the western Basque coast (N Spain). *Estuarine, Coastal and Shelf Science*, **56** (5), 1041-1054.
- Dudgeon, S., Kübler, J., Wright, W., Vadas Sr, R. & Petraitis, P.S., 2001. Natural variability in zygote dispersal of *Ascophyllum nodosum* at small spatial scales. *Functional Ecology*, **15** (5), 595-604.
- Eriksson, B.K. & Johansson, G., 2003. Sedimentation reduces recruitment success of *Fucus vesiculosus* (Phaeophyceae) in the Baltic Sea. *European Journal of Phycology*, **38** (3), 217-222.
- Eriksson, B.K., van Sluis, C., Sieben, K., Kautsky, L. & Råberg, S., 2011. Omnivory and grazer functional composition moderate cascading trophic effects in experimental *Fucus vesiculosus* habitats. *Marine Biology*, **158** (4), 747-756.
- Firth, L., Thompson, R., Bohn, K., Abbiati, M., Airoidi, L., Bouma, T., Bozzeda, F., Ceccherelli, V., Colangelo, M. & Evans, A., 2014. Between a rock and a hard place: Environmental and engineering considerations when designing coastal defence structures. *Coastal Engineering*, **87**, 122-135.
- Fish, J.D. & Fish, S., 1996. *A student's guide to the seashore*. Cambridge: Cambridge University Press.
- Fletcher, H. & Frid, C.L.J., 1996b. The response of an inter-tidal algal community to persistent trampling and the implications for rocky shore management. In Jones, P.S., Healy, M.G. & Williams, A.T. (ed.) *Studies in European coastal management*, Cardigan, Wales: Samara Publishing
- Fletcher, H. & Frid, C.L.J., 1996a. Impact and management of visitor pressure on rocky intertidal algal communities. *Aquatic Conservation: Marine and Freshwater Ecosystems*, **6**, 287-297.
- 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.
- Frieder, C., Nam, S., Martz, T. & Levin, L., 2012. High temporal and spatial variability of dissolved oxygen and pH in a nearshore California kelp forest. *Biogeosciences*, **9** (10), 3917-3930.
- Green, D., Chapman, M. & Blockley, D., 2012. Ecological consequences of the type of rock used in the construction of artificial boulder-fields. *Ecological Engineering*, **46**, 1-10.
- Guiry, M.D. & Guiry, G.M. 2015. AlgaeBase [Online], National University of Ireland, Galway [cited 30/6/2015]. Available from: <http://www.algaebase.org/>
- Hartnoll, R.G. & Hawkins, S.J., 1985. Patchiness and fluctuations on moderately exposed rocky shores. *Ophelia*, **24**, 53-63.
- 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. & Hartnoll, R.G., 1985. Factors determining the upper limits of intertidal canopy-forming algae. *Marine Ecology Progress Series*, **20**, 265-271.
- Holt, T.J., Hartnoll, R.G. & Hawkins, S.J., 1997. The sensitivity and vulnerability to man-induced change of selected communities: intertidal brown algal shrubs, *Zostera* beds and *Sabellaria spinulosa* reefs. *English Nature, Peterborough, English Nature Research Report No. 234*.
- Holt, T.J., Jones, D.R., Hawkins, S.J. & Hartnoll, R.G., 1995. The sensitivity of marine communities to man induced change - a scoping report. *Countryside Council for Wales, Bangor, Contract Science Report*, no. 65.
- Houghton, D.R., Pearman, I. & Tierney, D., 1973. The effect of water velocity on the settlement of swimmers 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., 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.
- Johnston, E.L. & Roberts, D.A., 2009. Contaminants reduce the richness and evenness of marine communities: a review and meta-analysis. *Environmental Pollution*, **157** (6), 1745-1752.
- Jonsson, P.R., Granhag, L., Moschella, P.S., Åberg, P., Hawkins, S.J. & Thompson, R.C., 2006. Interactions between wave action and grazing control the distribution of intertidal macroalgae. *Ecology*, **87** (5), 1169-1178.
- 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.
- Karez, R., Engelbert, S., Kraufvelin, P., Pedersen, M.F. & Sommer, U., 2004. Biomass response and changes in composition of

- ephemeral macroalgal assemblages along an experimental gradient of nutrient enrichment. *Aquatic Botany*, **78** (2), 103-117.
- 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.
- Khfaji, A.K. & Norton, T.A., 1979. The effects of salinity on the distribution of *Fucus ceranoides*. *Estuarine, Coastal and Shelf Science*, **8**, 433-439.
- Kibirige, I., Perissinotto, R. & Nozais, C., 2003. Grazing rates and feeding preferences of the mysid shrimp *Gastrosaccus brevifissura* in a temporarily open estuary in South Africa. *Marine Ecology Progress Series*, **251**, 201-210.
- Kinne, O., 1977. International Helgoland Symposium "Ecosystem research": summary, conclusions and closing. *Helgoländer Wissenschaftliche Meeresuntersuchungen*, **30**(1-4), 709-727.
- 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., Moy, F.E., Christie, H. & Bokn, T.L., 2006. Nutrient addition to experimental rocky shore communities revisited: delayed responses, rapid recovery. *Ecosystems*, **9** (7), 1076-1093.
- Kraufvelin, P., Ruuskanen, A., Nappu, N. & Kiirikki, M., 2007. Winter colonisation and succession of filamentous algae and possible relationships to *Fucus vesiculosus* settlement in early summer. *Estuarine Coastal and Shelf Science*, **72**, 665-674.
- Kylin, H., 1917. Kalteresistenz der Meerealen. *Bericht der Deutschen Botanischen Gesellschafter*, **35**, 370-384.
- Lein, T.E., 1984. Distribution, reproduction and ecology of *Fucus ceranoides* L. (Phaeophyceae) in Norway. *Sarsia*, **60**, 75-81.
- 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.
- Liddle, M.J., 1997. *Recreational ecology. The ecological impact of outdoor recreation and ecotourism*. London: Chapman & Hall.
- Littler, M. & Murray, S., 1975. Impact of sewage on the distribution, abundance and community structure of rocky intertidal macro-organisms. *Marine Biology*, **30** (4), 277-291.
- 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.
- 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.
- Neiva, J., Pearson, G.A., Valero, M. & Serrão, E.A., 2012. Drifting fronds and drifting alleles: range dynamics, local dispersal and habitat isolation shape the population structure of the estuarine seaweed *Fucus ceranoides*. *Journal of Biogeography*, **39** (6), 1167-1178.
- Niesenbaum R.A., 1988. The ecology of sporulation by the macroalga *Ulva lactuca* L. (chlorophyceae). *Aquatic Botany*, **32**, 155-166.
- Norton, T.A., 1986. The ecology of macroalgae in the Firth of Clyde. *Proceedings of the Royal Society of Edinburgh. Section B. Biological Sciences*, **90**, 255-269.
- Olsen, J.L., 2011. Stress ecology in *Fucus*: abiotic, biotic and genetic interactions. *Advances in Marine Biology*, **59** (57), 37.
- Pearson, G.A. & Brawley, S.H., 1996. Reproductive ecology of *Fucus distichus* (Phaeophyceae): an intertidal alga with successful external fertilization. *Marine Ecology Progress Series*. Oldendorf, **143** (1), 211-223.
- 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
- 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.
- Rohde, S., Hiebenthal, C., Wahl, M., Karez, R. & Bischof, K., 2008. Decreased depth distribution of *Fucus vesiculosus* (Phaeophyceae) in the Western Baltic: effects of light deficiency and epibionts on growth and photosynthesis. *European Journal of Phycology*, **43** (2), 143-150.
- Serrao, E.A., Kautsky, L., Lifvergren, T. & Brawley, S.H., 1997. Gamete dispersal and pre-recruitment mortality in Baltic *Fucus vesiculosus*. *Phycologia*, **36**, 101-102.
- Smith, G.M., 1947. On the reproduction of some Pacific coast species of *Ulva*. *American Journal of Botany*, **34**, 80-87.
- Suryono, C.A. & Hardy, F.G., 1997. Studies on the distribution of *Fucus ceranoides* L. (Phaeophyta, Fucales) in estuaries on the north-east coast of England. *Transactions of the Natural History Society of Northumbria*, **57**, 153-168.
- Tyler-Walters, H., 2005. *Laminaria hyperborea* with dense foliose red seaweeds on exposed infralittoral rock. *Marine Life Information Network: Biology and Sensitivity Key Information Sub-programme [on-line]*: Plymouth: Marine Biological Association of the United Kingdom. 2015(20/05/2015). <http://www.marlin.ac.uk/habitatsbasicinfo.php?habitatid=171&code=1997>
- UKNEA (UK National Ecosystem Assessment), 2011. The UK National Ecosystem Assessment: Synthesis of the Key Findings. *UNEP-WCMC, Cambridge*, pp. <http://uknea.unep-wcmc.org/>
- UKTAG, 2014. UK Technical Advisory Group on the Water Framework Directive [online]. Available from: <http://www.wfduk.org>
- 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.